JUN 1 8 1986 247

C 13.10:250-26

COMPLETED

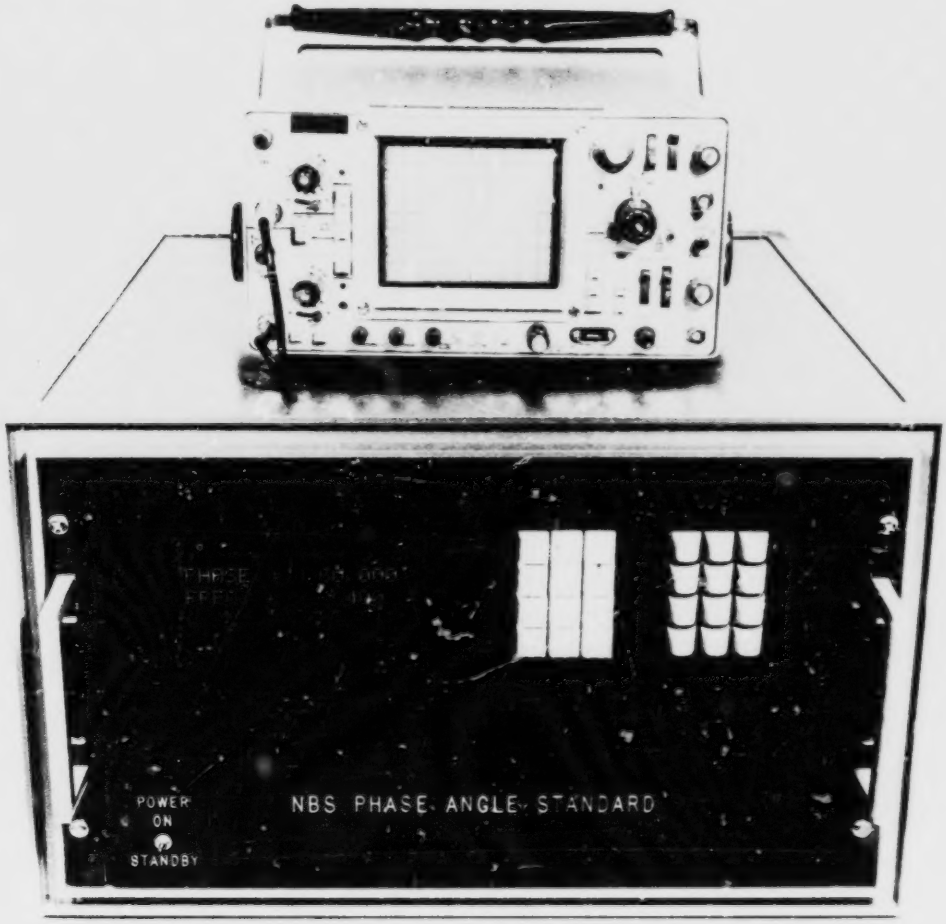
U.S. Department of Commerce
National Bureau of Standards

NBS MEASUREMENT SERVICES

Special Publication 250–26

NBS PHASE ANGLE CALIBRATION SERVICES

R. S. Turgel, J. M. Mulrow, and D. F. Vecchia



BEST COPY AVAILABLE

ORIGINAL

INTRODUCING THE CENTER FOR ELECTRONICS AND ELECTRICAL ENGINEERING

The Center for Electronics and Electrical Engineering (CEEE) is the component of the National Bureau of Standards charged with providing Bureau activities and services supporting electrotechnology. In response to identified and anticipated needs, Center programs provide national reference standards, measurement methods, supporting theory and data, and traceability to national standards. Beneficiaries are U.S. industry, other Government organizations, the academic community, and society at large. In fiscal year 1987, the Center calibrated nearly a thousand transfer standards for some 200 customers.

The Center is organized into four technical divisions, with the Electrosystems and Semiconductor Electronics Divisions at Gaithersburg, Maryland and the Electromagnetic Fields and Electromagnetic Technology Divisions at Boulder, Colorado. The Center provides **measurement research and services** for:

- Conducted electrical signals and energy in the Electrosystems Division:
  - dielectrics for advanced power systems
  - conducted electromagnetic interference
  - waveform synthesis
  - signal acquisition and processing
  - automatic test equipment
  - calibration/testing strategies
- Radiofrequency signals and interference in the Electromagnetic Fields Division:
  - radiofrequency to millimeter-wave electromagnetic fields and signals
  - general microwave and millimeter-wave instruments, components
  - microwave and millimeter-wave noise
  - microwave and millimeter-wave antenna systems
  - radiated electromagnetic interference; electromagnetic compatibility
  - monolithic microwave/millimeter-wave integrated circuits
  - materials properties measurements at high frequencies
- Lightwaves, cryogenics, and magnetics in the Electromagnetic Technology Division:
  - optical fibers; integrated electro-optics
  - superconducting materials
  - superconducting electronics
  - magnetic materials
- Semiconductor Electronics, in the Semiconductor Electronics Division:
  - semiconductor materials, such as silicon and gallium arsenide
  - semiconductor materials modification
  - semiconductor devices
  - integrated-circuit test structures for rapid process assessment

For information, contact the Center at 1-301-975-2220 or write to: The Center for Electronics and Electrical Engineering, Metrology Building Room B-358, National Bureau of Standards, Gaithersburg, MD 20899.

NBS MEASUREMENT SERVICES:
NBS Phase Angle Calibration Services

R. S. Turgel
Electrosystems Division
Center for Electronics and Electrical Engineering
National Engineering Laboratory
National Bureau of Standards
Gaithersburg, MD 20899

J. M. Mulrow and D. F. Vecchia
Statistical Engineering Division
Center for Applied Mathematics
National Engineering Laboratory
National Bureau of Standards
Boulder, CO 80303

May 1988

U.S. DEPARTMENT OF COMMERCE, C. William Verity, Secretary
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Director

Library of Congress Catalog Card Number: 88-600501

National Bureau of Standards Special Publication 250-26
Natl. Bur. Stand. (U.S.), Spec. Publ. 250-26, 114 pages (May 1988)
CODEN: XNBSAV

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1988

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9325

- - - PREFACE - - -

Calibrations and related measurement services of the National Bureau of Standards (NBS) provide the means for industry, government agencies, academia, and others to relate the measurements they make to national standards and, by extension, to the measurement systems of other countries throughout the world. It is of crucial importance to improving U.S. productivity, efficiency, and quality -- in short our competitive stance -- that measurements of appropriate accuracy can be made at all stages of product development, production, and marketing and that it is possible to refer the results of these measurements to each other in a meaningful way. NBS services provide essential support for satisfying these needs, as well as measurement needs arising from societal concerns such as health, safety, natural resources, and defense. The requirements of NBS clientele range from the highest levels of accuracy realizable from advanced science and technology to the practical levels of accuracy needed to support routine production. A reference-level measurement may be the result of days of painstaking individual effort or may be provided by a semi-automatic measuring system in minutes. The variation in customer needs and hence in NBS services responsive to those needs is great.

The more than 300 different calibration services, measurement assurance services, and special tests that are offered by NBS are described in NBS Special Publication 250, NBS Calibration Services Users Guide. The Guide provides essential technical details of NBS calibration and related measurement services, such as levels of accuracy provided by NBS and the requirements to be met by customers' transfer standards. It also provides information needed for placing orders for these services and identifies technical and administrative contacts for each service.

Technical descriptions in the Users Guide are intended to be restricted to the material needed by a potential customer to decide if a given service will meet that customer's needs. Frequently, a customer may be interested in more detailed and extensive information, such as the way in which the errors associated with a measurement are assessed. Beginning in 1987, NBS established a Special Publication 250 series which supplements the Guide. Each publication in this series provides a detailed technical description of a specific NBS calibration service, or closely related set of services, and includes:

- o specifications for the service
- o design philosophy and theory
- o description of NBS measurement system used to provide service
- o NBS operational procedures
- o measurement uncertainty assessment, including error budget, identification of systematic and random errors
- o NBS internal quality control procedures

Special Publication 250-26, **NBS Phase Angle Calibration Services**, describes special-test service offered under NBS Test Number 55110S by the Electronic Instrumentation and Metrology Group in the Electrosystems Division. Service 55110S is part of a series of services offered by the Division that are intended to support the application of modern electronic techniques to measurement problems.

Table of Contents

	Page
List of Tables	vi
List of Figures	vi
1. INTRODUCTION	1
2. DESCRIPTION OF SERVICE	1
3. DESIGN PHILOSOPHY	1
4. DESCRIPTION OF THE SYSTEM	2
5. CALIBRATION PROCEDURE	2
6. SYSTEMATIC ERRORS IN PHASE ANGLE STANDARD	3
7. CALIBRATION CURVE	4
7.1 Simple Linear Model	5
7.2 Least Squares Fit	6
7.3 Test of Model Adequacy	10
7.4 Tests of Slope and Intercept	11
7.5 Offset in Corrected Values	12
7.6 Calculation of Phase Meter Uncertainty	16
8. LIMITATIONS OF THE CALIBRATION CURVE	17
8.1 Lack of Precision	17
8.2 Nonlinearity of the Calibration Curve	17
8.3 Differences Among Repetitions	18
9. REFERENCES	20
APPENDIX A. Critical values of Student's t Distribution	21
APPENDIX B. Sample Calibration Reports	22
APPENDIX C Computer Program for Phase Meter Calibration	33

List of Tables

page

Table 1. Estimated Phase Angle Uncertainty 4

Table A-1 Critical Values $t_{\alpha/2}(\nu)$ of Student's t Distribution 21

List of Figures

Figure 1. Diagram of the calibration curve for a phase meter 5

Figure 2A. Differences Between Measured Phase Angles and Corresponding NBS Values, Plotted Against NBS Values (Example 1). 8

Figure 2B. Differences Between Measured Phase Angles and Corresponding NBS Values, Plotted Against NBS Values (Example 2). 8

Figure 3A. Measured Phase Angles Plotted Against Corresponding NBS Values (Example 3) 9

Figure 3B. Differences Between Measured Phase Angles and Corresponding NBS Values, Plotted Against NBS Values (Example 3). 9

Figure 4. Calibration curve for a phase meter with corresponding confidence bands 13

Figure 5. Changes in calibration curve from repetition to repetition . . 19

NBS PHASE ANGLE CALIBRATION SERVICE

Abstract

The National Bureau of Standards (NBS) offers a calibration service for audio-frequency phase meters. The calibrations are based on a phase angle standard developed at NBS that generates two sinusoidal signals displaced relative to one another by a precisely known phase angle over a frequency range of 2 hertz to 50 kilohertz. The signal amplitudes are independently adjustable on each channel from 0.5 volts to 100 volts. The angular resolution is better than 0.002° at the low end of the frequency range and decreases to 0.005° at the high end. The uncertainty of the phase angle between the two signals generated by the standard varies from 0.005° to 0.04°, depending on frequency and amplitude.

Using the phase angle standard, phase meter readings are obtained at selected test points. From the calibration data, the phase meter response characteristic is determined and is compared to that of an ideal meter having a linear characteristic. If the phase meter response conforms to the linear model, a straight-line calibration curve is derived from the data and serves to calculate corrected readings. From the statistical parameters associated with the calibration curve, it is possible to estimate the limits of offset between the calibrated meter and the calibration standard. By extension, the uncertainty of readings of the phase meter in the user's laboratory can be estimated.

Key Words: Calibration, Calibration Curve, Linear Model, Phase Meter, Phase Standard, Uncertainty.

1. INTRODUCTION

The measurement of phase angle is important in many applications encompassing diverse areas such as power systems, navigation, satellite tracking, and servo circuit design. Modern phase meters are capable of resolution of 0.01 degrees, so that the process of checking their calibration is far from trivial.

Phase angles, like voltage ratio, are dimensionless quantities and, in theory at least, can be reproduced at any time without reference to physical standards. In practice, however, doing so is a difficult task and prone to cumulative errors. It is, therefore, highly desirable and convenient to use a phase angle standard for phase meter calibrations to assure consistency of measurements.

The National Bureau of Standards (NBS) is providing a calibration service for audio frequency phase meters to make consistent and traceable phase measurement possible. This Technical Note describes the phase meter calibration procedure used at NBS and provides some of the statistical background for evaluating the accuracy of the calibrations.

2. DESCRIPTION OF SERVICE

NBS provides phase meter calibrations over a frequency range from 2 Hz to 50 kHz. The nominal frequency resolution of the test signal is 1 Hz up to 5 kHz and 10 Hz from 5 to 50 kHz. The frequency stability of the signal provided is of the order of 10 parts per million, and the accuracy of the frequency is limited by the synthesizer adjustment as described in [1]. The phase angle of the standard is insensitive to the exact frequency value and is not affected by frequency drifts.

The amplitudes of the two signals applied to the phase meter can be varied independently over a useful range from 0.5 to 100 volts, or 0.5 to 5 amperes with a special transconductance amplifier [2]. Since phase meters are generally not very sensitive to amplitude, no attempt is made to regulate the magnitude of the output voltages (or currents) precisely. The amplitude values are adjusted to within a few tenths of a percent, but should be regarded as nominal values only.

3. DESIGN PHILOSOPHY

Phase meter calibrations can be carried out by comparing the reading of the phase meter under test with that of a reference phase meter. For such a procedure to be valid, the signal source, although uncalibrated, must be well characterized. Frequency and phase stability, as well as spectral purity, of the test signals must have sufficiently tight tolerances so that the waveform will not influence the response of the phase meter. Rather than develop such a precision phase meter and a suitable signal source, it seemed preferable to

combine their attributes and develop a phase-calibrated signal source. The reasons for choosing this particular implementation, which is embodied in the NBS Phase Angle Standard, are discussed in [1].

4. DESCRIPTION OF THE SYSTEM

The NBS Phase Angle Standard, described in detail in [1], [3], [4], and [5] is a signal source that provides two sinusoidal voltage outputs displaced relative to each other by a known phase angle. To calibrate a phase meter, the meter is generally connected directly to the two outputs of the Phase Angle Standard. If one of the inputs to the phase meter requires a current, a specially designed transconductance amplifier [2] is connected between the Phase Angle Standard and the phase meter to be calibrated. The amplifier furnishes a current proportional to the Phase Angle Standard output voltage with a known and generally negligible additional phase offset. Further details can be found in [1] and [3].

5. CALIBRATION PROCEDURE

The calibration procedure is controlled from an instrument controller via a General Purpose Interface Bus (GPIB)[1]. If the instrument under test is also bus compatible, then the calibration can proceed almost completely automatically. In most cases, however, the phase meter output will have to be read from its own display and manually entered into the controller (computer).

Wherever possible, a second precision phase meter, used as a check standard, is connected in parallel with the instrument under test. Since the characteristics of the check standard are well-known, the measurement results obtained from it provide additional reassurance that the system is operating properly. The indicated phase angles are then recorded from the readouts of the phase meter under test and the check standard meter. The readings are entered into a computer (instrument controller) keyboard, or transferred directly to the controller via the GPIB, if provided.

The usual procedure consists of selecting 12 phase angles spanning the interval from 0° to 360° (or other intervals specifically requested by the customer) for each set of input voltage (current) and frequency conditions. Normally, four replicate readings are taken at each selected phase angle. The order of measurements is chosen at random such that one set of 12 phase angle measurements is completed before the next one is started and is arranged so that the same angle is never measured twice in succession. Because some phase meters have appreciable settling times, a variable delay is provided by the controller between setting the Phase Angle Standard and recording the reading. If the delay required to obtain consistent readings is longer than five seconds, the time interval is reported in the calibration report.

---

1 IEEE Standard 488-1978

All readings are recorded on magnetic tape or disk, whether entered manually or automatically via the bus. For the purposes of calculation, angles lying between 359 and 361 degrees are converted to corresponding values in the range of -1 to +1 degrees. On phase meters having more than one readout range, readings are taken on the 0 to 360 degree range whenever possible.

Each specified set of conditions of frequency and input voltages or currents is designated as a "Range," and phase angle data for each Range are treated independently. An exception is made if it is deemed necessary to retest a Range and if the results of both sets of measurements appear to come from the same (statistical) population. In that case the results of both Ranges are combined.

Immediately after completing the set of readings on a particular Range, a plot of differences between the phase meter readings and the corresponding phase angle settings on the Phase Angle Standard is obtained. This plot helps in checking for outliers or possible errors in the data entered. By superimposing a similar plot of the differences obtained from the check standard, similarities between the two sets of data can be examined. Normally, these two sets can be expected to be uncorrelated, and any obvious similarity may indicate an equipment malfunction.

After all the calibration data have been collected and have been given a preliminary check, as indicated above, the statistical procedures outlined below are applied to the data.

6. SYSTEMATIC ERRORS IN PHASE ANGLE STANDARD

The uncertainty of the phase angle between the two output signals generated by the Phase Angle Standard is a function of frequency as well as signal amplitude. The values of estimated uncertainty components are shown in Table 1. The values in this table are based on experimental data reported in [3] and measurements made during the development of the system. These values apply only for the Phase Angle Standard itself. For those calibrations requiring an output voltage in excess of 100 volts rms or an output current instead of a voltage, external amplifiers must be used. The phase shifts caused by these amplifiers, which may be of the order of degrees, must be compensated by an adjustment of the Phase Angle Standard. While the phase shifts in the external amplifiers are relatively stable with time, they do lead to an increased uncertainty of the phase angle of the system. The additional uncertainty component is assigned on the basis of phase stability determined by monitoring the system output with a bridge circuit [1]. The bridge circuit measures the phase error at a nominal 180-degree phase angle. Typically, for test parameters of 120 V, 5 A, and 60 Hz, the sum of the systematic uncertainty components due to the external amplifiers is increased to 0.025 degrees.

Table 1. Estimated Phase Angle Uncertainty

	60 Hz	400 Hz	5 kHz	15 kHz	30 kHz	50 kHz
	(Units of Millidegrees)					
Auto-Zero Corr.*	1	2	5	6	12	20
Linearity	2	2	3	10	15	20
7:1 Voltage Ratio	1	2	3	10	20	40

*The uncertainty due to frequency adjustment is included.

The correction determined by the auto-zero procedure can be verified experimentally from time-to-time using the bridge technique described in [1] and [2]. Experience gained so far seems to indicate that the residual error after the auto-zero correction is applied will not vary by more than one or two millidegrees over periods of a month or so. Stability of the auto-zero correction itself can be ascertained easily by noting the value for the correction displayed on the readout of the Phase Angle Standard. The value determined is recorded with the phase meter calibration data to obtain a history of the performance of the standard.

7. CALIBRATION CURVE

As outlined above, calibration of phase meters is achieved by intercomparison of readings from the phase meter under test with the corresponding values assigned to the NBS Phase Angle Standard. A functional relationship is then established between the phase meter measurements and the phase angle values of the standard, and the corrected readings of the user's phase meter are derived based on this functional relationship.

An illustration of such a simple relationship is shown in Figure 1, where the solid straight line represents the calibration curve fitted to all measurements. To make measurements with the user's phase meter, the observed values are related to the NBS values by means of the calibration curve which brings the corrected measurement results into close agreement with the standard. Schematically, for a future phase meter value, y, a dotted line is drawn through y parallel to the x-axis. At the point where it intersects the calibration curve, another dotted line is drawn parallel to the y-axis, and its point of intersection with the x-axis, x, is the corresponding calibrated value relative to NBS. The reader is referred to reference [6] for a more detailed discussion on the use of linear calibration curves.

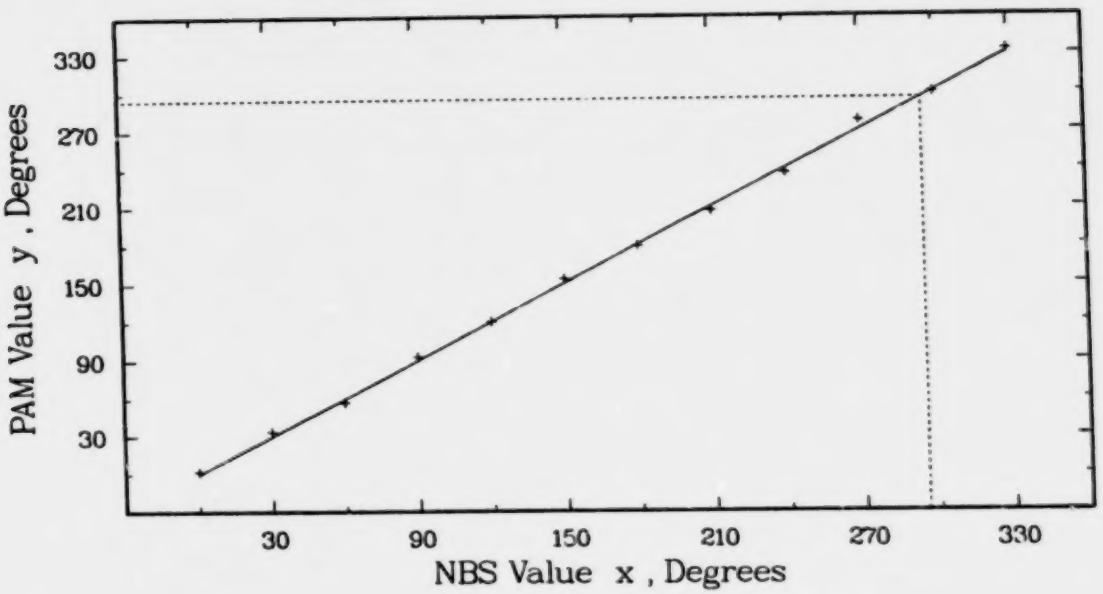


Figure 1. Diagram of the calibration curve for a phase meter

7.1 Simple Linear Model

The procedures and analyses discussed below are appropriate for calibrating phase meters that have an essentially linear response characteristic. A phase meter that has a linear response relative to the NBS Phase Angle Standard will exhibit the following behavior. An observed phase angle, y, will be related to the phase angle, x, assigned to the signals generated by the NBS Phase Angle Standard, plus random noise which in the linear expression is designated by a term, e.

$$y = a + bx + e.$$

For an ideal meter the slope, b, will equal 1, the intercept, a, will equal zero, and the scatter of random measurement errors will be sufficiently small for the measurement system.

To examine the relationship between the values of the NBS Phase Angle Standard and the observations from an actual user's phase meter, the observed phase angles are first fitted to a simple linear function of the NBS values, and then the adequacy of the straight-line fit is tested. If the linearity is acceptable, the statistical significance of differences of the estimated slope and intercept from their respective ideal values is checked.

If these statistical tests show that the user's phase meter offset is not negligible, thus indicating a need for correction of the phase meter readings, the fitted curve becomes the calibration curve for the user's phase meter. The uncertainty of the corrected values obtained from the calibration curve is then estimated using the procedure discussed below in sections 7.5 and 7.6.

BEST COPY AVAILABLE

7.2 Least Squares Fit

Given phase meter measurements y_{ij} corresponding to NBS phase angle values x_i, where i is the index of the selected phase angle and j denotes the repetition, a simple model to describe the phase meter behavior is given by:

$$y_{ij} = a + b\,x_i + e_{ij} , \quad \begin{cases} i = 1, \ldots, k \\ j = 1, \ldots, n \end{cases}$$

where the random measurement errors, e_{ij}, are typically assumed to have a Gaussian distribution with mean value zero and standard deviation σ, to be estimated.

Using a caret (^) to denote estimated parameter values, the least-squares estimates of the slope and intercept are:

$$\hat{b} = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n} (y_{ij}-\bar{y})\,(x_i-\bar{x})}{n \sum_{i=1}^{k} (x_i-\bar{x})^2}$$

$$\hat{a} = \bar{y} - \hat{b}\,\bar{x}$$

where

$$\bar{y} = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n} y_{ij}}{nk} \quad , \text{ and } \quad \bar{x} = \frac{\sum_{i=1}^{k} x_i}{k} .$$

The residuals from the fit are:

$$r_{ij} = y_{ij} - \hat{a} - \hat{b}\,x_i ,$$

and the residual standard deviation, which estimates σ, is:

$$s = \left(\frac{\sum_{i=1}^{k} \sum_{j=1}^{n} r_{ij}^2}{nk-2} \right)^{1/2} .$$

Two sample data sets will be used to illustrate the phase meter calibration computations. Figures 2A and 2B show examples of data from two meters. The plots are of the differences $(y_{ij}-x_i)$ versus x_i. For Example 1, three repetitions (n=3) of the phase meter measurements were obtained at 12 phase angle settings (k=12) on the NBS Phase Angle Standard. For Example 2, four repetitions (n=4) of the phase meter measurements were obtained at the same 12 phase angle settings (k=12) as in Example 1. Also, note that if the phase meter is in agreement with the NBS standard, the plot of the differences

should be randomly distributed about a horizontal line through zero as in Figure 2B. Thus the phase angle measurements in Figure 2A show that a slope of the calibration curve different from one ($b \neq 1$) will be necessary to correct the phase meter readings.

Plotting the differences between the observed phase angles and the corresponding NBS values against the NBS values will disclose any aberrant or systematic behavior of the user's phase meter. For example, oscillatory behavior of the data would suggest that the simple linear relationship does not represent the system. Example 3, shown in Figures 3A and 3B, illustrates this type of behavior. Figure 3A is a plot of y vs. x, and no noticeable nonlinearities are apparent. The same data are replotted in Figure 3B as the (y-x) differences vs. x, and a nonlinear pattern is now apparent. A statistical test for detecting such nonlinearity is discussed below.

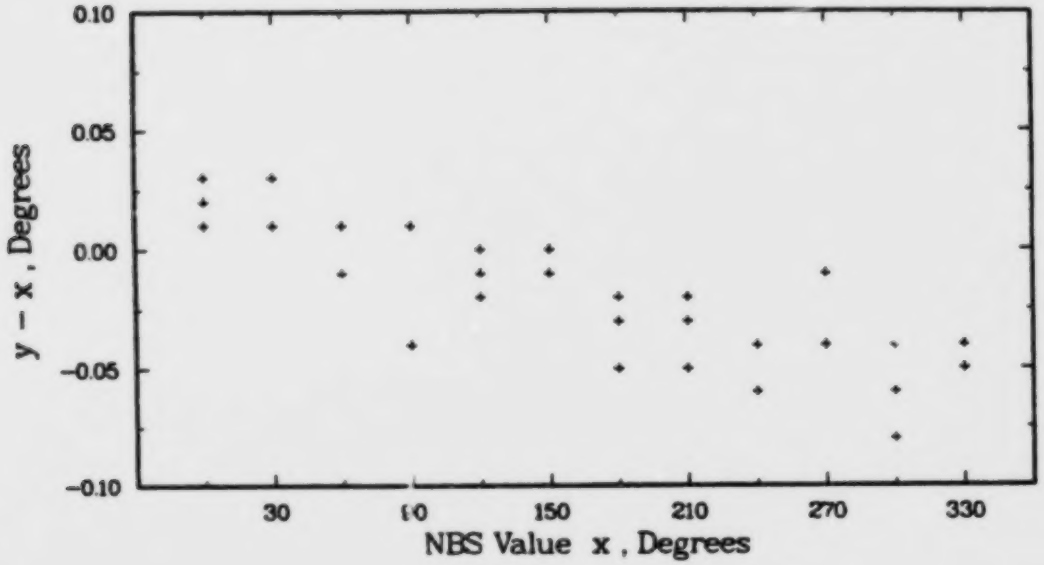


Figure 2A. Differences Between Measured Phase Angles and Corresponding NBS Values, Plotted Against NBS Values (Example 1).

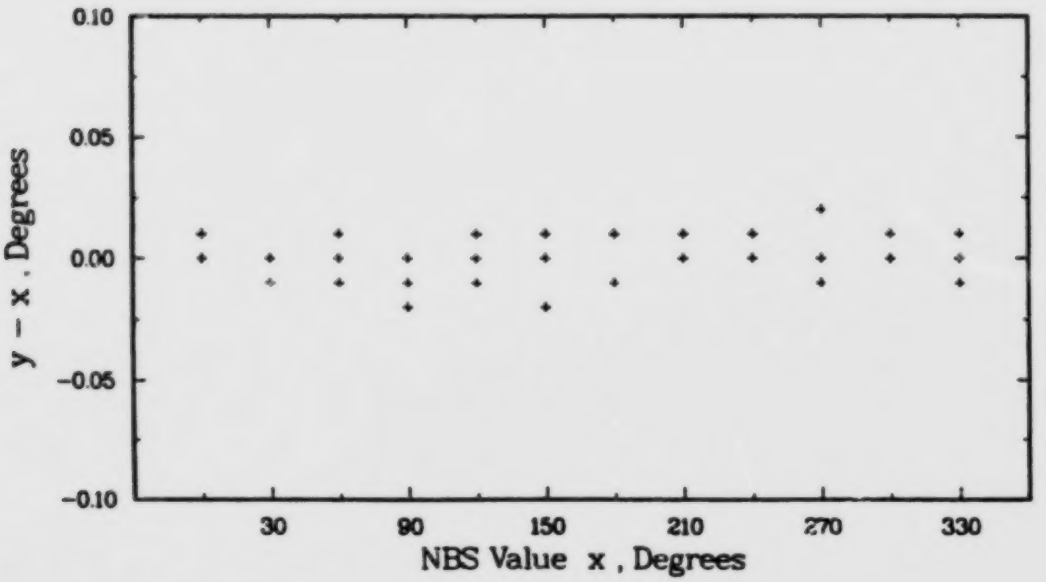


Figure 2B. Differences Between Measured Phase Angles and Corresponding NBS Values, Plotted Against NBS Values (Example 2).

BEST COPY AVAILABLE

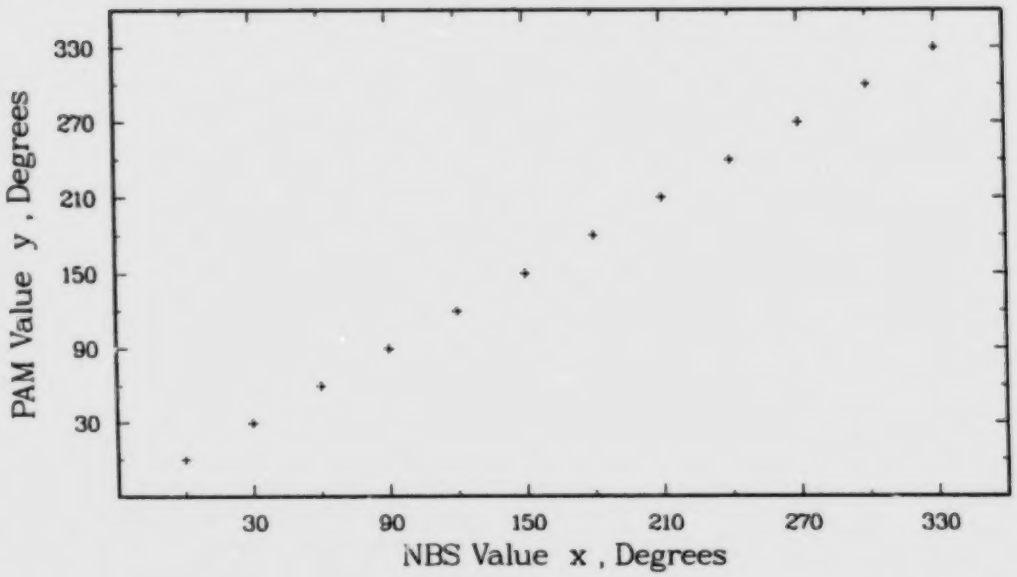


Figure 3A. Measured Phase Angles Plotted Against Corresponding NBS Values (Example 3)

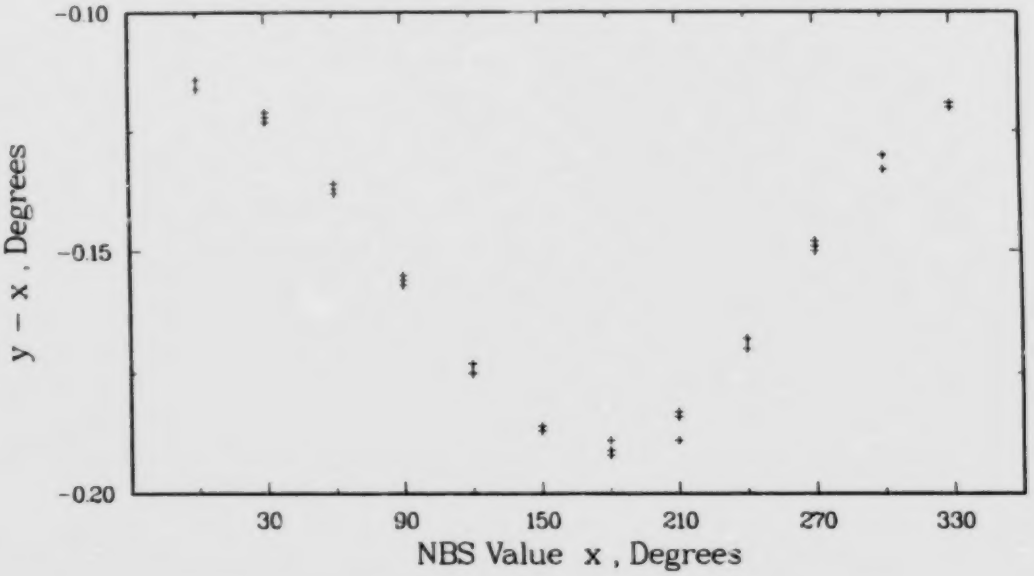


Figure 3B. Differences Between Measured Phase Angles and Corresponding NBS Values, Plotted Against NBS Values (Example 3).

BEST COPY AVAILABLE

7.3 Test of Model Adequacy

Before proceeding with the tests for the slope and intercept, it is confirmed that a simple linear function is adequate to relate phase meter measurements to the assigned values of the NBS Phase Angle Standard. A plot of the deviations from the linear fit provides insight into the model adequacy. A formal statistical test to decide whether or not a simple linear function of the phase meter measurements is an appropriate calibration curve is based on the information in the repeated measurements at each phase angle (see [7], page 33). The lack-of-fit test is obtained when the fitted value for each phase angle,

$$\hat{y}_i = \hat{a} + \hat{b}\, x_i , \qquad i = 1, \ldots, k$$

is compared to the average of the repeat measurements at corresponding phase angles:

$$\bar{y}_i = \frac{\sum_{j=1}^{n} y_{ij}}{n} .$$

Close agreement between the fitted values and these averages is evidence that the simple linear function is reasonable. Using the F statistic as a criterion, the calibration data are not consistent with a straight line model if:

$$F' = \frac{S_L^2}{S_e^2} > F_{0.01}(k-2,\ k(n-1))$$

where,

$$S_L^2 = \frac{n}{k-2} \sum_{i=1}^{k} (\hat{y}_i - \bar{y}_i)^2$$

$$S_e^2 = \frac{1}{k(n-1)} \sum_{i=1}^{k} \sum_{j=1}^{n} (y_{ij} - \bar{y}_i)^2$$

and $F_\alpha(k-2,\ k(n-1))$ is the upper one-percent point (for $\alpha = 0.01$) of the F distribution with k-2 degrees of freedom in the numerator and k(n-1) degrees of freedom in the denominator (see [7], page 37). Use of a small significance level ($\alpha = 0.01$) in the lack-of-fit test implies that we are only interested in detecting very substantial departures from linearity in the phase meter under test.

Generally, in statistical tests a convention exists in using α of 0.05, 0.01 or smaller. Alternatively, because the selection of a particular α level is somewhat arbitrary, it is common to report an attained significance level corresponding to the calculated value of a test statistic. A computed significance level near zero corresponds to a high degree of confidence that

the associated hypothesis is not tenable. For instance, in the lack-of-fit test, a computed significance level for F' of 0.004 would lead to the conclusion that the observed departure from linearity was statistically significant at the 0.004 level of probability.

7.4 Tests of Slope and Intercept

If the linear model is found to be adequate, the next step is to determine the test statistics, t_1 and t_2, to check if the intercept a is zero and if the slope b is one. The test statistics are as follows [7, page 26]:

$$t_1 = \frac{\hat{a}}{S(\hat{a})} \quad ; \qquad t_2 = \frac{\hat{b} - 1}{S(\hat{b})}$$

where

$$S(\hat{a}) = \left[\frac{\sum_{i=1}^{k} x_i^2}{n \sum_{i=1}^{k} (x_i - \bar{x})^2} \right]^{1/2} \cdot s \quad \text{and} \quad S(\hat{b}) = \left[\frac{1}{nk \sum_{i=1}^{k} (x_i - \bar{x})^2} \right]^{1/2} \cdot s \, .$$

A value of $|t_1| > t_{\alpha/2}(nk-2)$ indicates that the intercept is significantly different from zero, and a value of $|t_2| > t_{\alpha/2}(nk-2)$ indicates that the slope is significantly different from one.[2] The value of $t_{\alpha/2}(nk-2)$ can be found in a table of Student's t distribution, where α is the significance level of the test (typically, $\alpha = 0.05$) and $(k-2)$ is the number of degrees of freedom in the residual standard deviation (see, for example, Appendix A).

Alternatively, attained significance levels can be computed using each calculated value of t_1 or t_2. Computed significance levels near zero correspond to high confidence in asserting that the intercept and slope are significantly different from zero and one, respectively. For example, a computed significance level for t_2 of 0.05 or less indicates that the slope is probably different from one.

---

2 The parameters a and b are tested separately so that the nature of systematic offset (relative to the standard) can be ascertained. If the intercept differs appreciably from zero, but the slope is not significantly different from its ideal value, a simple additive constant would be sufficient to reduce this source of error. If the slope is significantly different from its ideal value, then there is a need to calculate individual corrections for every data point. However, the use of these two separate t-tests is not optimal if we actually wish to test simultaneously if a = 0 and b = 1. See [7, page 94] for a discussion of the best statistical procedure for simultaneous evaluation of the slope and intercept.

7.5 Offset in Corrected Values

The following procedure can be thought of as a determination of the practical, rather than the statistical, significance of the offset of a phase meter from the NBS assigned values. For example, tests on the slope and intercept may be statistically significant, but the consequences of ignoring one or both of these can be practically insignificant relative to the required accuracy or resolution of the phase meter.

To assess the overall disagreement between the user's phase meter and the NBS assigned values, statistical confidence limits can be computed for the offset (systematic error) in the expected reading of the phase meter relative to the NBS value. The term "expected reading" may be thought of either as the value produced by the phase meter in the absence of random measurement errors or, equivalently, as the limiting mean of a large number of repeat measurements corresponding to a fixed phase angle. For phase meters having a linear response relative to the NBS Phase Angle Standard, the expected reading at a given phase angle x, denoted by $E(y|x)$, is:

$$E(y|x) = a + bx.$$

Then, the offset between the phase meter and the NBS standard at phase angle x is given by:

$$\Delta_x = E(y|x) - x = a + (b - 1)x. \qquad (1)$$

Note that Δ_x is actually the systematic offset of an uncorrected reading on the phase meter. As we show below, with the calibration data obtained following the procedure described in section 5 and the computations given in section 7.2, the user can account for part or all of the offset by applying various corrections to the readings and then computing "bounds to offset," that depend on the respective corrections that are considered. These bounds represent a component of the overall measurement uncertainty.

In the calibration report, limits to offset from the NBS Phase Angle Standard are listed for phase meter corrections at three levels of complexity:

(1) NO CORRECTION: use the observed reading;
(2) CONSTANT CORRECTION: add a constant to the observed reading;
(3) FULL CORRECTION: use the complete calibration curve correction.

When the required accuracy of the phase meter is specified a priori, the computed limits to offset for levels (1) and (2) may be used for comparison to decide if a simple correction (or no correction) is sufficient to achieve the user's required accuracy. Error limits associated with the full correction represent the smallest bound to offset that is available and are non-zero only because of the random uncertainty in the calibration data used to compute the estimated calibration curve.

It is clear from equation (1) that the offset in a phase meter reading depends on the particular phase angle x that is measured. In general, however, we require the error limits over the whole range of the calibration

curve, not merely for the expected offset corresponding to a single phase angle. Therefore, the initial step toward estimating offsets for <u>any</u> phase angle x is to compute statistical confidence bands appropriate for the whole calibration curve over the entire range from 0° to 360° (or other intervals requested by the customer). For the straight line as a whole, confidence curves [7, page 31] are given by the equations:

$$\ell(x_t) = \hat{a} + \hat{b}x_t - R(x_t)$$

and (2)

$$u(x_t) = \hat{a} + \hat{b}x_t + R(x_t)$$

where

$$R(x_t) = s\sqrt{2\,F_{0.05}\,(2,\,k-2)}\left(\frac{1}{nk} + \frac{(x_t-\bar{x})^2}{n\sum_{i=1}^{k}(x_i-\bar{x})^2}\right)^{1/2}. \qquad (3)$$

In the equations, x_t denotes the "true," or NBS, phase angle ($0° \le x_t \le 360°$) and F is an appropriate upper percentage point of the F distribution (as an illustration we have used the upper 5 percent point).

Figure 4 is a diagram of a calibration curve with the corresponding confidence bands sketched about it. For any given phase angle setting of the NBS Phase Angle Standard, the true reading on the phase meter is expected to

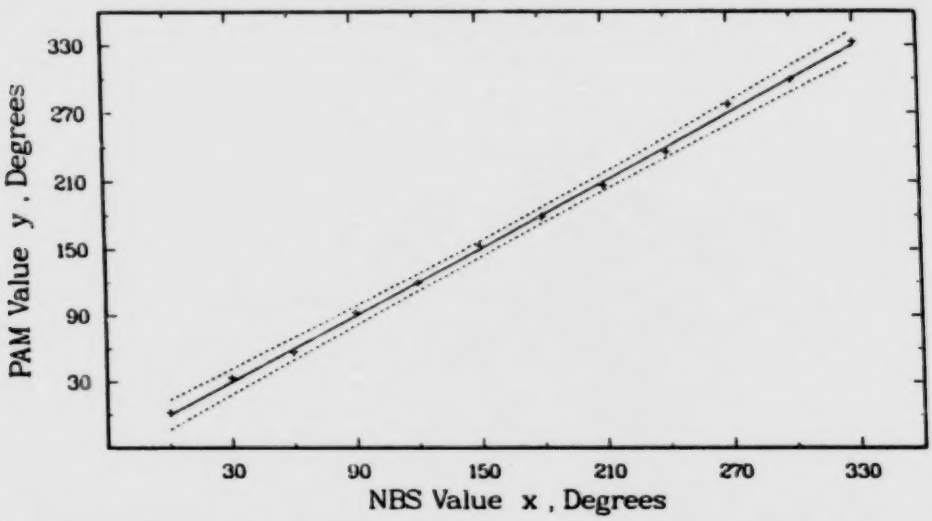


Figure 4. Calibration curve for a phase meter with corresponding confidence bands

be situated within the bands. Note that distance between the curves, $d(x_t)$ =

BEST COPY AVAILABLE

$u(x_t) - \ell(x_t)$, is different for each value of x_t, but the largest distance occurs at $x_t = 0°$ or $x_t = 360°$.

To estimate the offset of a phase meter, the calculations for each level of correction involve simple algebraic expressions derived from equation (2) by determining the limiting values for the whole calibration curve. For convenience, *the largest value of the estimated offset over the whole range of x is listed in the calibration report. Thus, the computed limit in each case should be interpreted as an upper bound to offset over the whole range of phase angles measured.*

LEVEL 1. NO CORRECTION: Offset in Uncorrected Values.

Lower and upper limits to the offset in a phase meter reading y_t corresponding to a "true" phase angle x_t, when there are no corrections applied to y_t, are given by:

$$L(x_t) = \hat{a} + (\hat{b} - 1)x_t - R(x_t)$$

and

$$U(x_t) = \hat{a} + (\hat{b} - 1)x_t + R(x_t)$$

where $R(x_t)$ is given in equation (3). The largest limits occur at either $x_t = 0°$ or $x_t = 360°$. (If another interval is requested by the customer, the endpoints of that interval are substituted for 0° and 360° where appropriate.)

The magnitude of the largest estimated offset for uncorrected values is:

$$\hat{\Delta}_{LEVEL1} = \text{maximum of } (|L(0°)| , |U(0°)| , |L(360°)| , |U(360°)|) . \quad (4)$$

The value of $\hat{\Delta}_{LEVEL1}$ is an estimated upper bound to the offset between an uncorrected phase meter reading and the corresponding NBS assigned value. If y denotes a phase meter reading and $\hat{x}$ denotes the associated "corrected"[3] value derived from y to bring a reading into agreement with the NBS Phase Angle Standard, then taking $\hat{x} = y$ indicates that no correction is applied. Other levels of correction in the discussion below are indicated by similar equations. Thus, $\hat{x} = y + A$ indicates that a constant correction is applied, and $\hat{x} = By + A$ indicates that a linear correction is applied, where A and B are computed constants.

To decide if the agreement of an uncorrected phase meter reading with the corresponding phase angle supplied by the NBS standard is acceptable for practical purposes, $\hat{\Delta}_{LEVEL1}$ may be compared to an a priori accuracy specification, δ, if given. Then, provided $\hat{\Delta}_{LEVEL1} \leq \delta$, it is sufficient to let $\hat{x} = y$ to bring the result of the measurement into the desired agreement with the standard. However, *it is important to note that this comparison ignores random measurement error in the phase meter reading.* A procedure for including the user's limits to random error in a combined uncertainty estimate is given in section 7.6.

---

3 $\hat{x}$ represents an estimate of the value the Phase Angle Standard would have to be set to in order to make the phase meter read a value y.

LEVEL 2. CONSTANT CORRECTION: Offset in $(y + A_2)$.

If we ignore the possible difference in the slope of the calibration curve from its ideal value ($b = 1$; therefore, we set $B_2 (= 1/b) = 1$), but correct for the displacement of the line, estimated by $A_2 = \bar{x} - \bar{y}$, then the corrected phase meter reading is given by:

$$\begin{aligned} \hat{x} &= y + (\bar{x} - \bar{y}) \\ &= y + A_2 \end{aligned}$$

where $\bar{x}$ and $\bar{y}$ are the sample means from the calibration data (see section 7.1). Lower- and upper-limits on the offset in a measurement corrected this way are:

$$\begin{aligned} L(x_t) &= (\hat{a} + A_2) + (\hat{b} - 1)x_t - R(x_t) \\ \text{and} \\ U(x_t) &= (\hat{a} + A_2) + (\hat{b} - 1)x_t + R(x_t) \end{aligned} \qquad (5)$$

where $R(x_t)$ is defined in equation (3). Note that the limits are calculated simply by adding A_2 to the corresponding limits for uncorrected values.

An estimated upper bound, $\hat{\Delta}_{LEVEL2}$, to the magnitude of the offset in values corrected by adding $A_2 = (\bar{x} - \bar{y})$ to observed readings is obtained from equation (4), but substituting the new limits at 0° and 360° given above in equation (5). The value $\hat{\Delta}_{LEVEL2}$ may be compared to an a priori limit δ, if appropriate.

LEVEL 3. FULL CORRECTION: Offset in $(B_3 \cdot y + A_3)$.

If no correction, or a constant correction, is deemed inadequate to bring the phase meter reading into agreement with the NBS standard, then the full calibration curve should be used for correction. To estimate the phase angle of the NBS standard that corresponds to the phase meter reading, y, the following equation is used:

$$\begin{aligned} \hat{x} &= \frac{y - \hat{a}}{\hat{b}} \\ &= B_3 y + A_3 \end{aligned}$$

where $B_3 = 1/b$, $A_3 = -\hat{a}/\hat{b}$, and $\hat{a}$, $\hat{b}$ are the least-squares estimates of the intercept and slope obtained from the fitted calibration curve. Lower and upper limits on the offset in a measurement corrected via the calibration curve are:

$$L(x_t) = -\frac{R(x_t)}{\hat{b}} \quad \text{and} \quad U(x_t) = +\frac{R(x_t)}{\hat{b}}$$

where $R(x_t)$ is given in equation (3). An estimated upper bound to the

magnitude of the offset is:

$$\hat{\Delta}_{LEVEL3} = \text{maximum of } (\ |R(0°)/\hat{b}| \ , \ |R(360°)/\hat{b}| \ ) \ .$$

Results of the calculations discussed in this section are illustrated in two sample Reports of Calibration given in Appendix B. In the first example, a comparison of the three offsets suggests that a full correction is probably appropriate for the phase meter under test. Offsets for the phase meter in the second example show that very little is gained by correcting observed measurements.

7.6 Calculation of Phase Meter Uncertainty

Regardless of the type of correction applied to phase meter readings, the procedure described above provides only one component of the overall uncertainty in a corrected measurement. That is, the computed bound $\hat{\Delta}$ may be thought of as an estimate of the possible offset, or systematic error, in a phase meter reading relative to the NBS standard *if the random error in the phase meter could be made negligible*. Statistical methods are used to obtain $\hat{\Delta}$ because the functional relationship between a phase meter and the NBS standard is not known exactly, but is estimated by a series of repeated measurements (so the calibration curve has an associated imprecision).

To estimate the overall uncertainty in a phase meter reading, information obtained by the user about the variability of repeated measurements on the phase meter may be combined with the estimated offset as follows. Data obtained from the user's measurement process may be used to compute an estimate, s_p, of the standard deviation of phase meter random errors under normal laboratory test conditions. Then a bound, E, to the overall disagreement between phase meter readings and the NBS assigned values for each type of phase meter correction may be calculated by:

(1) NO CORRECTION: $E_{LEVEL1} = \hat{\Delta}_{LEVEL1} + s_p \cdot t_{\alpha/2}(\nu_p)$

(2) CONSTANT CORRECTION: $E_{LEVEL2} = \hat{\Delta}_{LEVEL2} + s_p \cdot t_{\alpha/2}(\nu_p)$

(3) FULL CORRECTION: $E_{LEVEL3} = \hat{\Delta}_{LEVEL3} + B \cdot s_p \cdot t_{\alpha/2}(\nu_p)$

where respective values of $\hat{\Delta}$ are given in Section 7.5, $B = 1/\hat{b}$ is computed from the estimated slope of the calibration curve, and ν_p is the degrees of freedom associated with s_p. Tabled values from the Student's t distribution for $\alpha = 0.05$ and $\alpha = 0.01$ may be found in Appendix A. When sufficient data is used to compute s_p, e.g., if $\nu_p \geq 30$, then for $\alpha = 0.05$, t is approximately equal to 2.00.

The standard deviation that is used to calculate the phase meter uncertainty must have sufficient degrees of freedom to provide a realistic measure of phase meter precision. As a general rule, 15 degrees of freedom is a minimum for the initial computation of the standard deviation. As more repeat measurements are obtained, the standard deviation may be recomputed to take advantage of the increased data base, and assuming that the measurement procedure is stable, this will assure a more reliable value of the estimated

standard deviation.

A standard deviation based on as few as two data points can be combined with other similar estimates that have been obtained on separate occasions or at different phase angles to calculate what is called a "pooled" standard deviation. If the individual standard deviations are s_1, s_2, ..., s_k with degrees of freedom ν_1, ν_2, ..., ν_k, respectively, then the pooled standard deviation is:

$$s_p = \left(\frac{\nu_1 s_1^2 + \nu_2 s_2^2 + \ldots + \nu_k s_k^2}{\nu_1 + \nu_2 + \ldots + \nu_k} \right)^{1/2} .$$

The degrees of freedom associated with s_p is $\nu_p = \nu_1 + \nu_2 + \ldots + \nu_k$. Each of the individual standard deviations is assumed to be calculated from the usual formula for the estimated standard deviation,

$$s_2 = \sum (y_i - \bar{y})^2/(n - 1)$$

with (n-1) degrees of freedom. The sequence of repeat measurements y_1, y_2, ..., y_n used to calculate an individual s_i may be obtained by taking n independent readings on the phase meter for any fixed input signal. Estimates for various phase angles may be combined using the formula above.

8. LIMITATIONS OF THE CALIBRATION CURVE

Phase meters are normally designed to have a linear response characteristic, and the data obtained from them are sufficiently repeatable to make the steps outlined above for obtaining a linear calibration curve and estimation of error limits a valid procedure. In isolated cases, however, the assumptions underlying this procedure do not hold. The significant sources of error that may cause this condition are summarized below.

8.1 Lack of Precision

Lack of precision is the inability to repeat measurements accurately with the same phase meter under similar operating conditions which therefore increases the random error in the measurement. The calibration curve, however, is designed to reduce the systematic error and so cannot help to reduce the random error component. To obtain better precision, it is usually necessary to improve the physical components of the measurement system or their interaction.

8.2 Nonlinearity of the Calibration Curve

The assumption of linearity is essential for the calibration procedure described to be valid. A possible source of a nonlinear systematic error is the cross coupling of input signals within the phase meter. An example is shown in Figure 3B. If a portion of one of the input signals is coupled to the other through a mutual inductance, the resulting phase error will be

greatest when the coupled signal component is out of phase, at a nominal phase angle of 0° or 180° and least when the coupled component is in phase at 90° and 270° as shown in the figure.

Another type of nonlinearity can arise if the digital readout of the phase meter is not linear. The calibration curve could then be represented by a second or third order polynomial. In practice, however, it is more likely that such nonlinearities are small and masked by the random error of the meter.

8.3 Differences Among Repetitions

Several repeat measurements are made at each phase angle during a calibration. As mentioned, a set of readings is taken in a random order at all selected phase angles before a repeat set is started. When significant changes are apparent from set to set, possibly indicating short-term drifts, a calibration curve will not yield satisfactory results. Errors of this type can be checked by plotting differences between observed and standard phase angles for each set, as shown in Figure 5 (where there are no major visible changes). A formal statistical test for differences in calibration curves can be found in [6, page 43].

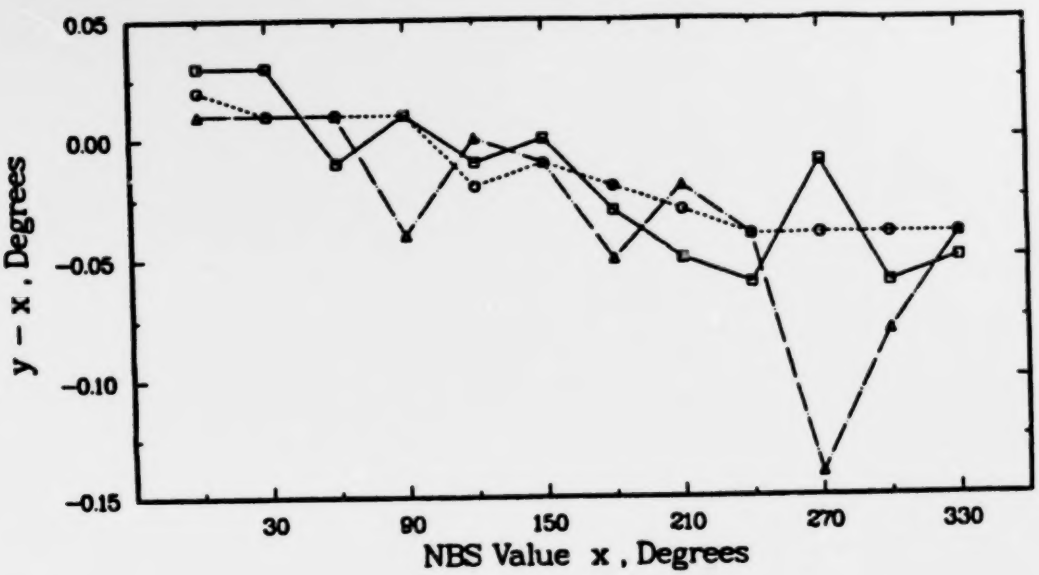


Figure 5. Changes in calibration curve from repetition to repetition

BEST COPY AVAILABLE

9. REFERENCES

[1] Turgel, R. S.; Oldham, N. M.; Stenbakken, G. N.; Kibalo, T. H.; "NBS Phase Angle Calibration Standard," *Nat. Bur. Stand. (U.S.) Technical Note 1144*, July 1981.

[2] Laug, O. B.,"A Wide-Band Transconductance Amplifier for Current Calibrations," *IEEE Transactions on Instrumentation and Measurement*, IM-34, No. 4, December 1985.

[3] Turgel, R. S.; "NBS 50 kHz Phase Angle Calibration Standard," *Nat. Bur. Stand. (U.S.) Technical Note 1220*, April 1986.

[4] Turgel, R. S.; Oldham, N. M.; "High-Precision Audio-Frequency Phase Calibration Standard," *IEEE Trans.Instrum. Meas.*, vol. IM-27, no. 4, December 1978.

[5] Turgel, R. S.; "A Precision Phase Angle Calibration Standard for Frequencies up to 50 kHz," *IEEE Trans.Instrum. Meas.*, vol. IM-34, no. 4, December 1985.

[6] Croarkin, C. M.; Varner, R. N.; "Measurement Assurance for Dimensional Measurement on Integrated-Circuit Photomasks," *Nat. Bur. Stand. (U.S.) Technical Note 1164*, August 1982.

[7] Draper, N. R.; Smith, H.; *Applied Regression Analysis*, 2nd Edition, Wiley and Sons Inc., New York, 1981.

APPENDIX A. Critical values of Student's t Distribution

Table A-1

Critical Values $t_{\alpha/2}(\nu)$ of Student's t Distribution

ν	α=0.05	α=0.01	ν	α=0.05	α=0.01
2	4.303	9.925	62	1.999	2.657
4	2.776	4.604	64	1.998	2.655
6	2.447	3.707	66	1.997	2.652
8	2.306	3.355	68	1.995	2.650
10	2.228	3.169	70	1.994	2.648
12	2.179	3.055	72	1.993	2.646
14	2.145	2.977	74	1.993	2.644
16	2.120	2.921	76	1.992	2.642
18	2.101	2.878	78	1.991	2.640
20	2.086	2.845	80	1.990	2.639
22	2.074	2.819	82	1.989	2.637
24	2.064	2.797	84	1.989	2.636
26	2.056	2.779	86	1.988	2.634
28	2.048	2.763	88	1.987	2.633
30	2.042	2.750	90	1.987	2.632
32	2.037	2.738	92	1.986	2.630
34	2.032	2.728	94	1.985	2.629
36	2.028	2.719	96	1.984	2.628
38	2.024	2.712	98	1.983	2.627
40	2.021	2.704	100	1.983	2.626
42	2.018	2.698	102	1.983	2.625
44	2.015	2.692	104	1.982	2.624
46	2.013	2.687	106	1.982	2.623
48	2.011	2.682	108	1.981	2.622
50	2.009	2.678	110	1.981	2.621
52	2.007	2.674	112	1.981	2.620
54	2.005	2.670	114	1.981	2.620
56	2.003	2.667	116	1.981	2.619
58	2.002	2.663	118	1.980	2.618
60	2.000	2.660	120	1.980	2.617
			∞	1.960	2.576

ν = number of degrees of freedom in the total standard deviation.

APPENDIX B. Sample Calibration Reports

The results of an NBS calibration are reported to the customer in a form similar to the examples shown in this appendix. There is some variation in the way the test is conducted and the results are reported depending on the design of the phase meter being calibrated.

The report identifies the customer, the instrument (by make, model, and serial number), the customer order number, the date, and ambient temperature during the test. For each set of current, voltage, and frequency conditions, the report provides an equation which can be used to correct the phase meter readings and lists in the appendix to the reort the estimated limit to offset from the NBS Phase Angle Standard that is associated with corrected values. Summary tables for each set of test conditions give adjusted values obtained from the correction equation for selected values of phase meter readings. Additional tables show the actual unprocessed calibration data. Coefficients and statistical parameters associated with the correction equation (calibration curve) are given in an appendix.

The data are taken using a computer program named "ϕCAL6." This program allows the operator to specify the phase angles test points, the number of readings at each, and all of the housekeeping information needed to document the measurement. This information includes the test date, file name under which the information and calibration data are stored on disk or tape, as well as the make, model, and serial number of the instrument under test and of the check standard phase meter (if used). While the calibration parameters associated with the calibration curve and the corrections derived from it are not stored, these can be recalculated by the program from the stored data, if needed.

A second program named "REPORT" calculates and formats the data and prints the calibration report using some of the subprograms associated with "ϕCAL6."

Two sample Reports of Calibration are shown in this appendix. In the first example, a comparison of the estimated offsets associated with uncorrected, partially corrected, and fully corrected phase meter readings (see section 7.5) suggests that a full correction is probably appropriate for the phase meter under test. Offsets for the phase meter in the second example show that very little is gained by correcting observed measurements. In fact, the summary table of adjusted values is suppressed in the calibration report since the adjustment obtained from the full correction equation is less than 0.01° for any observed reading on the phase meter.

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
GAITHERSBURG, MD 20899

REPORT OF CALIBRATION

Phase Meter
[redacted] Model [redacted], Serial No. [redacted]

Submitted by

[redacted]
P. O. Box [redacted]
[redacted], [redacted]

The phase meter was tested in April 1987 using the NBS Phase Angle Calibration Standard.[4] The ambient temperature was 23 ± 2° C. The phase meter under test, as well as the Phase Angle Calibration Standard, were under power for more than 3 hours before readings were taken.

For the specified current, voltage, and frequency conditions, three readings were taken at 12 test points (phase angles) selected in a random order. The NBS Phase Angle Standard was set to the desired phase angle, and the digital readout of the phase meter under test was read and recorded. The time constant in the response of the phase meter required a timed delay of 30 seconds before taking readings to obtain consistent results.

No adjustments of the phase meter were made at any time. The range switch provided on the phase meter was operated so that readings fell into an interval from -1 to 359 degrees wherever possible. Readings in the interval from 359 to 360 degrees were converted to an interval from -1 to 0 degrees for purposes of computation.

During the tests the test signal frequencies was maintained at constant values with a frequency stability better than 10 parts per million and with an uncertainty of less than ±0.01 Hz if below 5 kHz and ±0.1 Hz from 5 to 50 kHz.

---

4 NBS Technical Notes 1144 (July 1981) and 1220 (April 1986)

Phase Meter
[redacted] Model [redacted]
Serial No. [redacted]

The systematic uncertainty in the value of the NBS Phase Angle Standard is estimated to be less than 0.003 degrees at the currents, voltages, and frequencies used in this test. For the present data, based on replication readings, the limit to offset from the values provided by the NBS Phase Angle Calibration Standard for a corrected phase angle using the equation below, is estimated to be less than 0.020 degrees. The overall uncertainty of corrected phase angle measurements depends on the variability of repeat measurements on the phase meter under normal laboratory test conditions. The estimated standard deviation of repeat measurements at NBS was 0.022 degrees. Under similar operating conditions, the overall disagreement between a corrected phase meter reading and the NBS standard would be estimated to be less than 0.064 degrees[5].

For the Director
National Engineering Laboratory

Barry A. Bell, Group Leader
Electronic Instrumentation and Metrology
Electrosystems Division

Test No. 722-[redacted]-87
Order No. [redacted]
Date: April, 1987

---

5 NBS Technical Ncte XXXX, p. yy

Phase Meter
[redacted] Model [redacted]
Serial No. [redacted]

Reference Signal Voltage: 30.00 V
Variable Phase Signal Voltage: 30.00 V
Frequency: 60 Hz

Corrected Phase Angle:* $x' = -0.019407 + 1.000251\,y$

Table of Corrected Phase Angles (x') in Degrees*

OBSERVED PHASE ANGLE (Degrees)	CORRECTED PHASE ANGLE (Degrees)	OBSERVED PHASE ANGLE (Degrees)	CORRECTED PHASE ANGLE (Degrees)
0	-0.02	180	180.03
10	9.98	190	190.03
20	19.99	200	200.03
30	29.99	210	210.03
40	39.99	220	220.04
50	49.99	230	230.04
60	60.00	240	240.04
70	70.00	250	250.04
80	80.00	260	260.05
90	90.00	270	270.05
100	100.01	280	280.05
110	110.01	290	290.05
120	120.01	300	300.06
130	130.01	310	310.06
140	140.02	320	320.06
150	150.02	330	330.06
160	160.02	340	340.07
170	170.02	350	350.07

* Calculated values based on linear model (see appendix)

Phase Meter
[redacted] Model [redacted]
Serial No. [redacted]

Unprocessed Calibration Data for Range:

Reference Signal Voltage: 30.00 V
Variable Phase Signal Voltage: 30.00 V
Frequency: 60 Hz

NBS STANDARD (Degrees)	METER UNDER TEST (Degrees)	NBS STANDARD (Degrees)	METER UNDER TEST (Degrees)
0.00	0.03	180.00	179.97
0.00	0.02	180.00	179.98
0.00	0.01	180.00	179.95
30.00	30.03	210.00	209.95
30.00	30.01	210.00	209.97
30.00	30.01	210.00	209.98
60.00	59.99	240.00	239.94
60.00	60.01	240.00	239.96
60.00	60.01	240.00	239.96
90.00	90.01	270.00	269.99
90.00	90.01	270.00	269.96
90.00	89.96	270.00	269.86
120.00	119.99	300.00	299.94
120.00	119.98	300.00	299.96
120.00	120.00	300.00	299.92
150.00	150.00	330.00	329.95
150.00	149.99	330.00	329.96
150.00	149.99	330.00	329.96

Appendix

The calibration of this phase meter provides an equation to correct the reading obtained from the phase meter so that the result of the measurement will be close in agreement with the corresponding value supplied by the NBS Phase Angle Standard. These corrections are calculated from the unprocessed calibration data obtained during the test, which are shown on separate pages.

Because random fluctuations tend to mask the limiting mean of the phase meter response at any particular test point, the corrections calculated are based on predicted values. These values are obtained by fitting the unprocessed data (y) for each set of current, voltage, and frequency conditions to an equation which models the average response of the phase meter to phase angles (x) supplied by the NBS standard.

Reference Signal Voltage:	30.00 V
Variable Phase Signal Voltage:	30.00 V
Frequency:	60 Hz

Predicted value	$y' =$ 0.019402	+ 0.999749 · x	(degrees)
Standard errors of coefficients	(0.006952)	(0.000036)	(degrees)
Significance levels[6]	(0.009)	(0.000)	

Residual standard deviation	$s =$ 0.022188	$2s =$ 0.04436	(degrees)
Lack-of-fit	$F' =$ 0.466		
Significance level[7]	(0.895)		

Estimated limits of systematic offset from NBS:

without corrections	$(x' = y)$	0.091	(degrees)
with a constant correction	$(x' = y + 0.262)$	0.070	(degrees)
using the fitted linear equation	(see above)	0.020	(degrees)

---

6 Significance levels are derived using statistical tests (Student's t-distribution) to decide if the intercept and slope of the fitted straight line are different from their ideal values, zero and one, respectively. A level near zero (less than or equal to 0.05) shows that the associated parameter is probably different from the ideal value.

7 The significance level of F' is associated with an objective statistical test for the adequacy of a linear model relating the user's phase meter response and the NBS assigned values. Significance levels near zero (less than or equal to 0.01) indicate that the assumption of a straight line as a model for the phase meter response may be incorrect. However, if the variability of the repeat readings is of the same order as the resolution of the meter, and the data points are therefore not normally distributed, the table of values on which this test is based are not applicable.

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
GAITHERSBURG, MD 20899

REPORT OF CALIBRATION

Phase Meter
[redacted] Model [redacted], Serial No. [redacted]

Submitted by

[redacted] Street
[redacted]

The phase meter was tested in August 1982 using the NBS Phase Angle Calibration Standard.[8] The ambient temperature was 23 ± 2° C. The phase meter under test, as well as the Phase Angle Calibration Standard, were under power for more than 3 hours before readings were taken.

For the specified current, voltage, and frequency conditions, four readings were taken at 12 test points (phase angles) selected in a random order. The NBS Phase Angle Standard was set to the desired phase angle, and the digital readout of the phase meter under test was read and recorded. The time constant in the response of the phase meter required a timed delay of 30 seconds before taking readings to obtain consistent results.

No adjustments of the phase meter were made at any time. The range switch provided on the phase meter was operated so that readings fell into an interval from -1 to 359 degrees wherever possible. Readings in the interval from 359 to 360 degrees were converted to an interval from -1 to 0 degrees for purposes of computation.

During the tests the test signal frequencies was maintained at constant values with a frequency stability better than 10 parts per million and with an uncertainty of less than ±0.01 Hz if below 5 kHz and ±0.1 Hz from 5 to 50 kHz.

---

8 NBS Technical Notes 1144 (July 1981) and 1220 (April 1986)

Phase Meter
[redacted] Model [redacted]
Serial No. [redacted]

The systematic uncertainty in the value of the NBS Phase Angle Standard is estimated to be less than 0.004 degrees at the currents, voltages, and frequencies used in this test. For the present data, based on replication readings, the limit to offset from the values provided by the NBS Phase Angle Calibration Standard for a corrected phase angle using the equation below, is estimated to be less than 0.011 degrees. The overall uncertainty of corrected phase angle measurements depends on the variability of repeat measurements on the phase meter under normal laboratory test conditions. The estimated standard deviation of repeat measurements at NBS was 0.008 degrees. Under similar operating conditions, the overall disagreement between a corrected phase meter reading and the NBS standard would be estimated to be less than 0.027 degrees[9].

For the Director
National Engineering Laboratory

Barry A. Bell, Group Leader
Electronic Instrumentation and Metrology
Electrosystems Division

Test No. 722-[redacted]-82
Order No. [redacted]
Date: August, 1982

9 NBS Technical Note XXXX, p. yy

Phase Meter
[redacted] Model [redacted]
Serial No. [redacted]

Reference Signal Voltage:	5.00 V
Variable Phase Signal Voltage:	100.00 V
Frequency:	60 Hz

No correction is needed to bring the observed phase angle reading into agreement with the NBS standard.

Phase Meter
[redacted] Model [redacted]
Serial No. [redacted]

Unprocessed Calibration Data for Range:

Reference Signal Voltage: 5.00 V
Variable Phase Signal Voltage: 100.00 V
Frequency: 60 Hz

NBS STANDARD (Degrees)	METER UNDER TEST (Degrees)	NBS STANDARD (Degrees)	METER UNDER TEST (Degrees)
0.00	0.00	180.00	179.99
0.00	0.00	180.00	179.99
0.00	0.01	180.00	180.01
0.00	0.00	180.00	179.99
30.00	29.99	210.00	210.00
30.00	30.00	210.00	210.01
30.00	29.99	210.00	210.00
30.00	30.00	210.00	210.01
60.00	60.00	240.00	240.01
60.00	60.00	240.00	240.01
60.00	60.01	240.00	240.00
60.00	59.99	240.00	240.01
90.00	89.98	270.00	270.00
90.00	89.99	270.00	269.99
90.00	90.00	270.00	270.00
90.00	90.00	270.00	270.02
120.00	119.99	300.00	300.01
120.00	120.00	300.00	300.00
120.00	120.00	300.00	300.00
120.00	120.01	300.00	300.00
150.00	150.01	330.00	330.00
150.00	150.01	330.00	330.00
150.00	150.00	330.00	330.01
150.00	149.98	330.00	329.99

Appendix

The calibration of this phase meter provides an equation to correct the reading obtained from the phase meter so that the result of the measurement will be close in agreement with the corresponding value supplied by the NBS standard. These corrections are calculated from the unprocessed calibration data obtained during the test, which are shown on separate pages.

Because random fluctuations tend to mask the limiting mean of the phase meter response at any particular test point, the corrections calculated are based on predicted values. These values are obtained by fitting the unprocessed data (y) for each set of current, voltage, and frequency conditions to an equation which models the average response of the phase meter to phase angles (x) supplied by the NBS standard.

Reference Signal Voltage:	5.00 V
Variable Phase Signal Voltage:	100.00 V
Frequency:	60 Hz

Predicted value	$y' = -0.002581 + 1.000020 \cdot x$		(degrees)
Standard errors of coefficients	(0.002324)	(0.000012)	(degrees)
Significance levels[10]	(0.273)	(0.100)	

Residual standard deviation	$s = 0.008548$	$2s = 0.01708$	(degrees)
Lack-of-fit	$F' = 0.811$		
Significance level[11]	(0.620)		

Estimated limits of systematic offset from NBS:

without corrections	$(x' = y)$	0.011	(degrees)
with a constant correction	$(x' = y + 0.262)$	0.010	(degrees)
using the fitted linear equation	(see above)	0.007	(degrees)

---

10 Significance levels are derived using statistical tests (Student's t-distribution) to decide if the intercept and slope of the fitted straight line are different from their ideal values, zero and one, respectively. A level near zero (less than or equal to 0.05) shows that the associated parameter is probably different from the ideal value.

11 The significance level of F' is associated with an objective statistical test for the adequacy of a linear model relating the user's phase meter response and the NBS assigned values. Significance levels near zero (less than or equal to 0.01) indicate that the assumption of a straight line as a model for the phase meter response may be incorrect. However, if the variability of the repeat readings is of the same order as the resolution of the meter, and the data points are therefore not normally distributed, the table of values on which this test is based are not applicable.

APPENDIX C

Computer Program for Phase Meter Calibration

A computer program has been developed to implement the procedures and calculations given in this NBS Technical Note. The program sets the NBS Phase Standard to the desired operating conditions and records the readings of the phase meter under test. The computer (instrument controller) can receive the readings directly from the phase meter, if the meter has a GPIB interface, otherwise the digital display of the phase meter is read and the data are entered manually via the keyboard. The data can be stored on disk for future recall, and after all the data for a range have been collected, the program attempts to fit the data to a straight line, using the phase angle settings of the NBS standard as an independent variable. Finally, the corrected phase meter readings and the statistical parameters resulting from the fit are printed out as the calibration report using the second section of the program.

This appendix contains a complete listing of the main program sections and the sub-programs which are written in BASIC for the Hewlett-Packard[12] Model 85 configured with 32K of RAM, the Advanced Programming ROM, the Mass Storage ROM, and the I/O ROM. The code may require modification if the program is to be used on another computer. Minor modification may also be required to interface to a different phase angle standard, or if a printer other than the Qume Sprint 11 Plus with a RS-232-C Model 1 Interface[12] is used.

The listing incorporates two main programs. The first program called "ϕCAL6" controls the operation of the NBS Phase Angle Standard, the test procedure, and performs the statistical analysis. The second program, called "REPORT," formats and prints the calibration report. The structure of these two programs is shown in figures C-1 and C-2. The programs invoke various subprograms which comprise the remainder of the listing. Because of the limited memory available, the subprograms are swapped in and out of memory as needed. Despite the memory limitation, the programs contain many explanatory comments which will assist in understanding the program procedures. Lists of cross references and descriptions of variables are also provided.

To calibrate a phase meter several steps have to be followed. First, the Phase Meter Calibration Program (ϕCAL6) is loaded and run. Then, a new test is initialized by selecting the "New Test" option in the menu. This step includes entering administrative information about the customer and the phase meter to be tested. Next, using the "Test Points" selection from the main menu, the range parameters and the phase angles to be tested are set up. Using the "Enter Data" option more information about the number of readings per test point, the time allowed for the meter to settle, the peripheral bus addresses, etc. are set up. The actual calibration data is then taken either fully automatically using the GPIB or entered manually for test points selected in a random order by the program.

---

12 To describe the system discussed adequately, commercial equipment and parts are identified by the manufacturer's name and model number. In no case does such identification imply a recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

After all the readings for one range have been taken, the data are stored with the "Save" selection from the menu. An optional error plot can then be obtained to check for outliers or errors in data entry. If the data seem satisfactory, the "Fit" option can be used to provide statistical information on how well the data fit the linear model. Corrected phase meter readings are then calculated using the linear equation.

To print the calibration report, the program "REPORT" is loaded and run. This program recovers the calibration data from the disk storage and calculates the numerical information needed. The report can then be printed with a format that allows some flexibility by exercising options from the menu.

ACKNOWLEDGEMENT.

The authors would like to thank Mr. Joseph E. Lapp for his thorough revision of the computer programs which made the programs run more efficiently and for the addition of explanatory comments throughout the code so that it could be followed more easily.

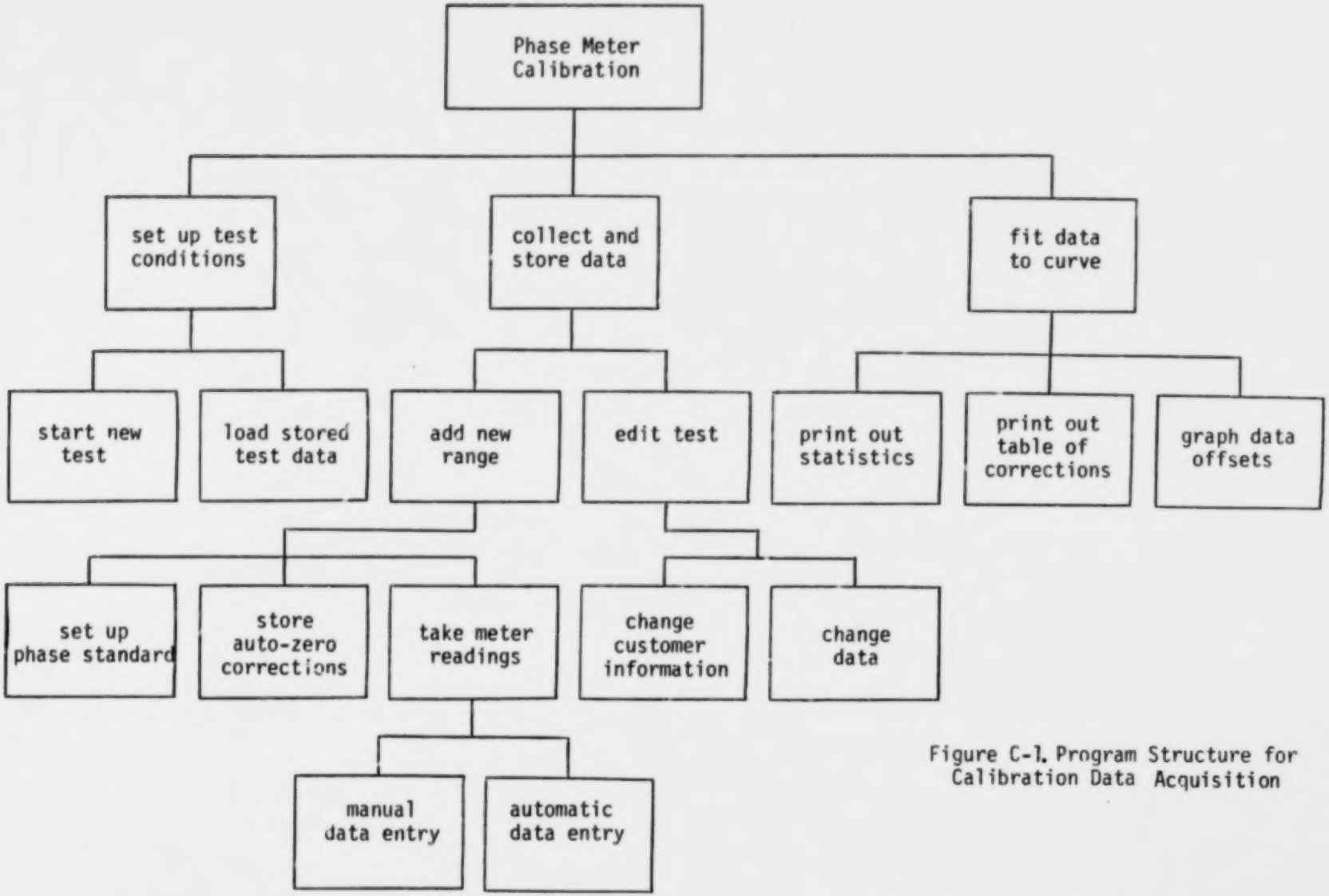


Figure C-1. Program Structure for Calibration Data Acquisition

BEST COPY AVAILABLE

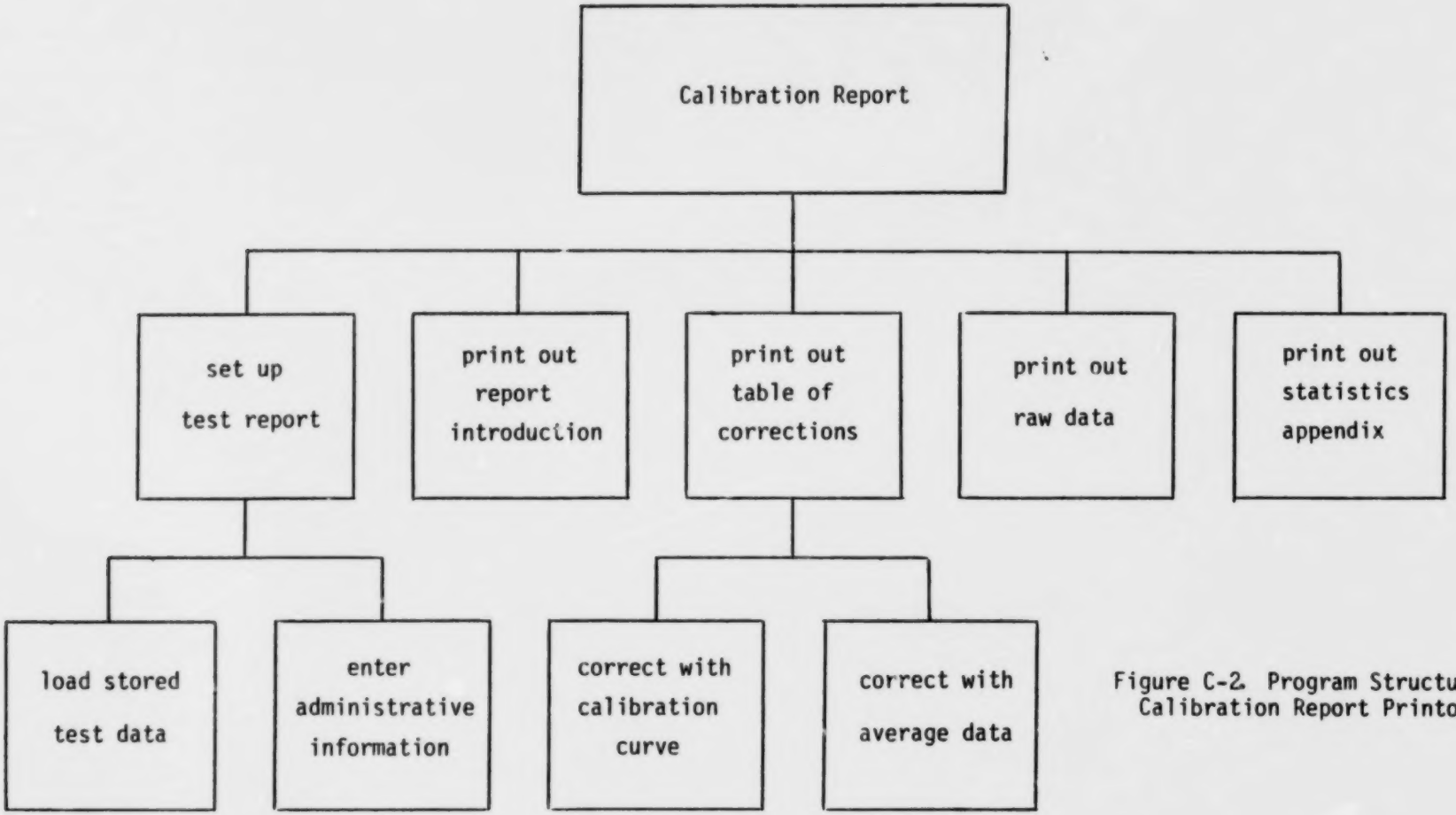


Figure C-2. Program Structure for Calibration Report Printout

BEST COPY AVAILABLE

36

```
100 ! Phase Meter Calibration Program
105 !
110 ! This program sets the date and time and dispatches the user
115 ! from the main menu to the calibration routines.  JUL 87
120 !
125 ON KEY# 1,"MENU" GOTO 225
130 OPTION BASE 1@ INTEGER B1(100),B2(100)
135 COM C$[60],R(10,4),C(100,8),D(100,8),A(5),TO$[100]
140 DIM I2$[20],I3$[20],M1$[160],M2$[40],Z(1)
145 SARRAY M1$,M2$,TO$ @ C$[60]=" "
150 !
155 ! Prompt user for date and time.
160 !
165 ! R(1,1)=0 to skip prompt concerning saving of previous file.
170 R(1,1)=0 @ CLEAR @ DISP "Phase Meter Calibration Program" @ DISP
175 DISP " < k1 > returns you to menu." @ DISP
180 CALL "QUERY" ( "Enter date (MM/DD/YYYY).",R,Y,D$ ) @ ON R GOTO 185,200,225
185 DISP @ CALL "QUERY" ( "Enter time (HH:MM:SS).",R,Y,T$ )
190 ON R GOTO 195,185,225
195 D=VAL(D$[9,10])*1000+MDY(D$)-MDY("12/31/"&VAL$(VAL(D$[7,10])-1)) @ SETTIME H
MS(T$),D
200 ! S1$=date; TIME$=time
205 S$=DATE$ @ S1$=S$[4,6]&S$[7,8]&"/19"&S$[1,2] @ M=2
210 !
215 ! Main menu.
220 !
225 SLET M1$(1) = "Stored File"
230 SLET M1$(2) = "New File"
235 SLET M1$(3) = "Edit File"
240 SLET M1$(5) = "Range List"
245 SLET M1$(6) = "Test Data"
250 SLET M1$(7) = "Check Data"
255 SLET M1$(9) = "Enter Data"
260 SLET M1$(10) = "Test Points"
265 SLET M1$(11) = "Init Check"
270 SLET M1$(12) = "Find Fit"
275 SLET M1$(13) = "Plot Test"
280 SLET M1$(14) = "Plot Check"
285 SLET M1$(15) = "Save Data"
290 CLEAR @ C=0 @ KO=0 @ CALL "MENU" ( M,M1$,C ) @ M=15
295 ON C GOTO 315,345,385,100,395,430,450,100,485,520,525,580,610,635,655
300 !
305 ! Load stored file.
310 !
315 GOSUB 680 @ ON R GOTO 225,320,225
320 CALL "LOAD" ( C$,A(),R(,),D(,),C(,),B1(),B2(),DO$,TO$ )
325 SCRATCHSUB "LOAD" @ GOTO 225
330 !
335 ! Start new file.
340 !
345 GOSUB 680 @ ON R GOTO 225,350,225
350 CALL "INITAR" ( A(),B1(),B2(),C(,),D(,),R(,),TO$ ) @ SCRATCHSUB "INITAR"
355 C$=" " @ C$[60]=" " @ C$[2]=C$
360 CLEAR @ CALL "HEADER" ( C$,S1$,R1,R(,),1,N1,MO,TO$,DO$ )
365 SCRATCHSUB "HEADER" @ GOTO 225
```

```
370 !
375 ! Edit header, ranges, auto-zero data, test data, and check data.
380 !
385 CALL "EDITFI" ( C$,A(),B1(),B2(),C(,),D(,),DO$,MO,N$,R(,),S1$,TO$ )
390 SCRATCHSUB "EDITFI" @ GOTO 225
395 !
400 ! List range parameters.
405 !
410 DISP "Range R(,)" @ DISP @ FOR A=1 TO 8
415 DISP USING 420 ; A,R(A,1),R(A,2),R(A,3),R(A,4) @ NEXT A
420 IMAGE 3D,2X,3D,2X,3D.D,2X,3D.D,2X,5D
425 DISP @ DISP "Press <CONT> to continue." @ PAUSE @ GOTO 225
430 !
435 ! Observe test data.
440 !
445 CALL "DATA" ( D(,),B1(),N$ ) @ SCRATCHSUB "DATA" @ GOTO 225
450 !
455 ! Observe check data.
460 !
465 CALL "DATA" ( C(,),B2(),N$ ) @ SCRATCHSUB "DATA" @ GOTO 225
470 !
475 ! Begin or continue test.
480 !
485 CALL "GET_PARAMS" ( R,A(),T1,TO$,A1,A2,A3,F2,F3,I2$,I3$,P2,P3 )
490 SCRATCHSUB "GET_PARAMS" @ IF FLAG(5) THEN GOTO 225
495 CALL "GET_DATA" ( R,B1(),B2(),T1,A1,A2,A3,F2,F3,I2$,I3$,P2,P3,S1$,DO$,Z )
500 SCRATCHSUB "GET_DATA" @ IF Z=1 THEN 225
505 !
510 ! Initialize ranges.
515 !
520 CALL "GETRNG" ( A(),C(,),D(,),R(,),B1(),B2() ) @ SCRATCHSUB "GETRNG" @ GOTO
225
525 !
530 ! Initialize check standard.
535 !
540 CLEAR @ DISP "Is a check standard being used  for this test?"
545 CALL "YESNO" ( R ) @ ON R GOTO 555,550,225
550 CFLAG 1 @ GOTO 225
555 SFLAG 1 @ CALL "HEADER" ( C$,S1$,R1,R(,),2,N1,MO,TO$,DO$ )
560 SCRATCHSUB "HEADER" @ GOTO 225
565 !
570 ! Invoke fit routines.
575 !
580 ALPHA 1 @ CLEAR @ C=0 @ K0=0
585 SLET M2$(1) = "Fit Test Data" @ SLET M2$(2) = "Fit Check Data"
590 CALL "MENU" ( 2,M2$,C ) @ ON C GOTO 595,600
595 CALL "FIT" ( C$,R(,),D(,),B1(),S1$,TO$,DO$,1 ) @ GOTO 605
600 CALL "FIT" ( C$,R(,),C(,),B2(),S1$,TO$,DO$,0 )
605 SCRATCHSUB "FIT" @ GOTO 225
610 !
615 ! Plot test data.
620 !
625 CALL "PLOT" ( C$,D(,),R(,),B1(),R1,S1$,1,TO$,DO$ )
630 SCRATCHSUB "HEADER" @ SCRATCHSUB "PLOT" @ GOTO 225
```

```
635 !
640 ! Plot check data.
645 !
650 CALL "PLOT" ( C$,C(,),R(,),B2(),R1,S1$,0,TO$,DO$ ) @ GOTO 630
655 !
660 ! Save file.
665 !
670 CALL "STORE" ( C$,A(),R(,),D(,),C(,),B1(),B2(),DO$,TO$ )
675 SCRATCHSUB "STORE" @ GOTO 225
680 !
685 ! Warn user about pending loss of data.
690 !
695 ! Skip warning if no data has been entered.
700 IF R(1,1)=0 THEN R=2 @ RETURN
705 CLEAR @ DISP "Should previous file be saved?"
710 CALL "YESNO" ( R ) @ RETURN
```

VAR	OCCURS IN LINE	
B1()	130 ,320 ,350 ,385 445 ,495 ,520 ,595 625 ,670	no. of readings at each point of the test meter
B2()	130 ,320 ,350 ,385 465 ,495 ,520 ,600 650 ,670	no. of readings at each point of the check meter
C $	135 ,145 ,320 ,355 355 ,355 ,355 ,360 385 ,555 ,595 ,600 625 ,650 ,670	this string contains information about the test that is extracted from the table of contents. C$[1,30]=customer name; C$[31,40]=test date; C$[41,50]=serial no.; C$[60]=folder no.
R (,)	135 ,170 ,320 ,350 360 ,385 ,415 ,415 415 ,415 ,520 ,555 595 ,600 ,625 ,650 670 ,700	array of parameters for each of the 8 ranges. R(r,1)=no. of first test point of range; R(r,2)=reference channel voltage (or current if negative); R(r,3)=variable channel voltage or current; R(r,4)=frequency
C (,)	135 ,320 ,350 ,385 465 ,520 ,600 ,650 670	check meter data. 1st subscript=point no.; C(p,1)=ideal reading; C(p,2-7)=repeat readings; C(p,8)=average of readings
D (,)	135 ,320 ,350 ,385 445 ,520 ,595 ,625 670	test meter data. (described in C(,) above)
A ( )	135 ,320 ,350 ,385 485 ,520 ,670	A(1)=next available test point; A(2)=present range; A(3)=no. of readings to take; A(4)=reading on.
T0$	135 ,145 ,320 ,350 360 ,385 ,485 ,555 595 ,600 ,625 ,650 670	array of strings containing meter information. T0$(1),T0$(2),T0$(3)=manufacturer, model, serial no. of test meter; T0$(4),T0$(5),T0$(6)=manufacturer, model, serial no. of check meter.
I2$	140 ,485 ,495	instructions to set up test meter for auto reading.
I3$	140 ,485 ,495	instructions to set up check meter for auto reading.
M1$	140 ,145 ,225 ,230 235 ,240 ,245 ,250 255 ,260 ,265 ,270 275 ,280 ,285 ,290	array of strings of main menu options
M2$	140 ,145 ,585 ,585 590	array of strings of fit menu options. used to select whether to fit test or check data.
Z ()	140	dummy array
R	180 ,180 ,185 ,190 315 ,345 ,485 ,495 545 ,545 ,700 ,710	used for two purposes; gives information about user's reply and is a temporary register for the present range.
Y	180 ,185	dummy variable
D $	180 ,195 ,195 ,195	string into which user enters the date
T $	185 ,195	string into which user enters the time
D	195 ,195	Julian value of date
S $	205 ,205 ,205 ,205	string copy of Julian date
S1$	205 ,360 ,385 ,495 555 ,595 ,600 ,625 650	mm/dd/yyyy format of date
M	205 ,290 ,290	no. of options in menu passed to MENU routine
C	290 ,290 ,295 ,580 590 ,590	no. of selected menu option
K0	290 ,580	unused variable
D0$	320 ,360 ,385 ,495 555 ,595 ,600 ,625 650 ,670	date of test. loaded tests may have dates differing from the present date
R1	360 ,555 ,625 ,650	dummy variable
N1	360 ,555	dummy variable
M0	360 ,385 ,555	dummy variable
N $	385 ,445 ,465	dummy string
A	410 ,415 ,415 ,415 415 ,415 ,415	loop control
T1	485 ,495	WAIT between readings
A1	485 ,495	address of phase standard
A2	485 ,495	address of test meter
A3	485 ,495	address of check meter
F2	485 ,495	test meter multiplier for automatic readings
F3	485 ,495	check meter multiplier for automatic readings
P2	485 ,495	position of reading in test meter input
P3	485 ,495	position of reading in check meter input
Z	495 ,500	flag to abort test for main menu

```
100 SUB "A-ZERO" (A,R,D(,),F)
105 !
110 ! This program takes auto-zero samples to find the span and
115 ! average.  At user's request it will record the span and
120 ! the last correction.  JUL 87
125 !
130 ! INPUT: D(,)=data, F=flag to skip initial prompt.
135 !
140 OPTION BASE 1@ SFLAG 5 @ IF F THEN GOTO 155
145 CLEAR @ DISP "Do you want an auto-zero sample?" @ CALL "YESNO" ( K )
150 ON K GOTO 155,240,245
155 CLEAR @ S=D(92,R) @ DISP USING "D,30A" ; S," of 4 samples have been taken."
160 ! L=smallest correction, H=highest corr., T=sum of corrs.,
165 ! C=no. of corrs. in T.
170 L=361 @ H=-361 @ T,C=0 @ S=S+1 @ IF S=5 THEN S=1
175 DISP USING "41A,D,A" ; "Next stored sample will occupy  position ",S,"." @ D
ISP
180 ! Do auto-zero.
185 D$="LRFAQLFQLFFQR" @ Q=3 @ CALL "TALK" ( A,D$,Q )
190 IF Q<>-1 THEN DISP "Auto-zero was UNSUCCESSFUL." @ WAIT 1500 @ GOTO 145
195 Q=VAL(D$[8,16]) @ L=MIN(L,Q) @ H=MAX(H,Q) @ T=T+Q @ C=C+1
200 DISP USING 205 ; H-L,T/C @ DISP
205 IMAGE "running span     =",2DZ.3D / "running average =",2DZ.3D
210 ! Increase sample size on user request.
215 DISP "Do you want another reading?" @ CALL "YESNO" ( K ) @ ON K GOTO 185,225
,245
220 !
225 DISP @ DISP "Do you want to store this" @ DISP " sample?"
230 CALL "YESNO" ( K ) @ ON K GOTO 235,145,245
235 D(92,R)=S @ D(92+R,S*2-1)=H-L @ D(92+R,S*2)=Q
240 CFLAG 5
245 SCRATCHSUB "TALK" @ SUBEXIT
```

VAR	OCCURS IN LINE	
A	100 ,185	address of phase standard
R	100 ,155 ,235 ,235 235	present range
D (,)	100 ,155 ,235 ,235 235	test meter data. (see main program xref)
F	100 ,140	flag to skip "Do you want an auto-zero?" prompt
K	145 ,150 ,215 ,215 230 ,230	reply to yes or no prompt
S	155 ,155 ,170 ,170 170 ,170 ,175 ,235 235 ,235	no. of samples taken
L	170 ,195 ,195 ,200 235	smallest auto-zero correction
H	170 ,195 ,195 ,200 235	highest auto-zero correction
T	170 ,195 ,195 ,200	sum of corrections in present sample
C	170 ,195 ,195 ,200	no. of auto-zeros taken for sample
D $	185 ,185 ,195	correction read from standard
Q	185 ,185 ,190 ,195 195 ,195 ,195 ,235	multi-purpose variable. passes no. of queries to TALK and returns with -1 if TALK succeeded. on line 195 Q is the read correction

```
100 SUB "CHKRNG" (Z,A(),R(,))
105 !
110 ! This program will delete the present range if its test
115 ! points overflow the data arrays.  JUL 87
120 !
125 OPTION BASE 1
130 Z=1 @ IF A(1)<=91 THEN SUBEXIT
135 Z=0 @ A(1)=R(A(2),1) @ R(A(2),2),R(A(2),3),R(A(2),4)=0
140 CLEAR @ DISP "Maximum number of test points   reached.  RANGE DELETED."
145 DISP @ DISP "Press <CONT>." @ PAUSE
150 SUBEXIT
```

VAR	OCCURS IN LINE	
Z	100 ,130 ,135	set if there isn't room for the range
A ( )	100 ,130 ,135 ,135 135 ,135 ,135	A(1)=next available test point; A(2)=present range
R (,)	100 ,135 ,135 ,135 135	array of range parameters. (see xref in main program)

```
100 SUB "DATA" (D(,),B(),N$) ! JUL 87
105 !
110 ! This program displays phase angle and auto-zero data.
115 !
120 N$="" @ OPTION BASE 1@ DIM M$[40]
125 !
130 ! Have user select which data to see.
135 !
140 SARRAY M$ @ SLET M$(1) = "Angle Data" @ SLET M$(2) = "Auto-Zero Data"
145 CALL "MENU" ( 2,M$,C ) @ IF C=2 THEN 345
150 !
155 ! View phase angle data.
160 !
165 ! Prompt user for test points to see.
170 CLEAR @ CALL "QUERY" ( "Enter first test point to be     seen.",C,A2,Z$ )
175 IF A2<1 OR A2>91 THEN DISP "Data out of range." @ DISP @ GOTO 170
180 ON C GOTO 190,170,185
185 N$=CHR$(128) @ SUBEXIT
190 DISP @ CALL "QUERY" ( "Enter last test point to be     seen.",C,A3,Z$ )
195 IF A3<1 OR A3>91 THEN DISP "Data out of range." @ DISP @ GOTO 190
200 ON C GOTO 215,190,205
205 N$=CHR$(128) @ SUBEXIT
210 ! Function to keep angle within range of -1 to 359.
215 DEF FND(X) = X-360*(X>359 AND X<361)
220 ! Now show the data.
225 S=0 @ N=0
230 FOR A=A2 TO A3
235 IF B(A)=0 THEN DISP USING 240 ; A;D(A,1) @ GOTO 285
240 IMAGE /3D,1X,3D.3D,"  *** NO DATA ***"
245 DISP USING 250 ; A;D(A,1);B(A);D(A,8);D(A,2);D(A,3);D(A,4);D(A,5);D(A,6);D(A
,7)
250 IMAGE /3D,1X,3D.3D,2X,3D,2X,3D.3D,2(/3X,2(3D.3D,3X),3D.3D)
255 D8=FND(D(A,8))
260 IF B(A)<2 THEN 285
265 FOR B=2 TO B(A)+1
270 S=S+(FND(D(A,B))-D8)^2
275 NEXT B
280 N=N+B(A)-1
285 NEXT A @ IF N=0 THEN 315
290 ! Show the statistical info.
295 DISP USING 300 ; SQR(S/N)
300 IMAGE //"standard deviation = ",DZ.4D/"[replication]"
305 DISP USING 310 ; 3*SQR(S/N),N
310 IMAGE " 3s= ",17DZ.4D/" degrees of freedom = ",5D
315 DISP @ DISP @ DISP "Press <CONT> to continue."
320 PAUSE
325 SUBEND
330 !
335 ! Display auto-zero info for a given range.
340 !
345 CLEAR @ CALL "QUERY" ( "Enter range to examine.",C,R,Z$ )
350 IF R<1 OR R>8 THEN 345
```

```
355 ON C GOTO 360,345,185
360 IF D(92,R)=0 THEN DISP @ DISP "NO DATA AVAILABLE FOR THAT RANGE" @ WAIT 2000
 @ GOTO 185
365 CLEAR @ DISP USING 370 ; R
370 IMAGE / "Range ",D," Auto-Zero Data" //"  Sample    Span   Final Corr." //
375 FOR I=1 TO 4 @ DISP USING 380 ; I,D(92+R,I*2-1),D(92+R,I*2) @ NEXT I @ GOTO
315
380 IMAGE 5D,7DZ.3D,5DZ.3D
```

VAR	OCCURS IN LINE	
D (,)	100 ,235 ,245 ,245 245 ,245 ,245 ,245 245 ,245 ,255 ,270 360 ,375 ,375	any meter data. (see main program xref)
B (,)	100 ,235 ,245 ,260 265 ,280	no. of readings at each point of either meter
N $	100 ,120 ,185 ,205	contains CHR$(128) to request main menu
M $	120 ,140 ,140 ,140 145	array of strings of menu options
C	145 ,145 ,170 ,180 190 ,200 ,345 ,355	contains no. of menu option selected or value of user's request on QUERY
A2	170 ,175 ,175 ,230	first test point to be seen
Z $	170 ,190 ,345	dummy string
A3	190 ,195 ,195 ,230	last test point to be seen
S	225 ,270 ,270 ,295 305	standard deviation
N	225 ,280 ,280 ,285 295 ,305 ,305	no. of readings used to calculate deviation
A	230 ,235 ,235 ,235 245 ,245 ,245 ,245 245 ,245 ,245 ,245 245 ,245 ,255 ,260 265 ,270 ,280 ,285	test point no. and loop control
D8	255 ,270	average reading at point A
B	265 ,270 ,275	reading no. loop control
R	345 ,350 ,350 ,360 365 ,375 ,375	range no.
I	375 ,375 ,375 ,375 375	loop control

```
100 SUB "EDIT" (R(,),D(,),B(),N$,J)
105 !
110 ! This program allows the user to change ranges and test and
115 ! check data.  JUL 87
120 !
125 ! INPUT: J=1 to edit ranges; J=2 to edit data points.
130 !
135 OPTION BASE 1
140 N=0
145 ON J GOTO 165,230
150 !
155 ! Edit user-specified range.
160 !
165 CLEAR @ CALL "QUERY" ( "Enter range to be edited.",X,R,Y$ )
170 ON X GOTO 175,165,275
175 IF R<1 OR R>8 THEN 165
180 CLEAR @ GOSUB 285
185 DISP @ DISP "Make corrections, then press     <CONT> to continue." @ PAUSE
190 IMAGE A,"(",2D,",",D  ,")= ",M2DZ.2D
195 CLEAR @ GOSUB 285
200 IMAGE /,"Are data OK now?"
205 DISP USING 200 ;
210 CALL "YESNO" ( X ) @ ON X GOTO 275,175,275
215 !
220 ! Edit user-specified data point.
225 !
230 CLEAR @ DISP "Enter data point to be edited." @ IF N#0 THEN DISP N;" is the
default."
235 CALL "QUERY" ( "",X,N,Y$ )
240 ON X GOTO 245,230,275
245 IF N<1 OR N>91 THEN 230
250 GOSUB 320
255 DISP @ DISP "Make corrections, then press     <CONT> to continue." @ PAUSE
260 CLEAR @ GOSUB 320
265 DISP USING 200 ;
270 CALL "YESNO" ( X ) @ ON X GOTO 275,230,275
275 SUBEXIT
280 !
285 ! Routine to display range information.
290 !
295 FOR I=1 TO 4
300 DISP USING 190 ; "R",R,I,R(R,I)
305 NEXT I
310 RETURN
315 !
320 ! Routine to display data points.
325 !
330 S=0
335 FOR I=1 TO 8
340 IF I>1 AND I<=B(N)+1 THEN S=S+D(N,I)-360*(D(N,I)>359 AND D(N,I)<361)
345 IF I=8 AND B(N)<>0 THEN D(N,8)=S/B(N)
350 DISP USING 190 ; "D",N,I,D(N,I)
355 NEXT I
360 IF B(N)<>0 THEN D(N,8)=S/B(N)
365 DISP USING 370 ; N,B(N)
370 IMAGE "B(",DD,")= ",2D
375 RETURN
380 SUBEND
```

VAR	OCCURS IN LINE	
R (,)	100 ,300	array of range parameters. (see main program)
D (,)	100 ,340 ,340 ,340 345 ,350 ,360	test or check meter data. (see main program xref)
B (,)	100 ,340 ,345 ,345 360 ,360 ,365	no. of readings at each point of test or check meter
N $	100	unused
J	100 ,145	J=1 to edit ranges; J=2 to edit data
N	140 ,230 ,230 ,235 245 ,245 ,340 ,340 340 ,340 ,345 ,345 345 ,350 ,350 ,360 360 ,360 ,365 ,365	no. of data point to edit
X	165 ,170 ,210 ,210 235 ,240 ,270 ,270	numerical value of the user's request
R	165 ,175 ,175 ,300 300	range no.
Y $	165 ,235	dummy string
I	295 ,300 ,300 ,305 335 ,340 ,340 ,340 340 ,340 ,345 ,350 350 ,355	loop control
S	330 ,340 ,340 ,345 360	sum of readings at a data point

```
100 SUB "EDITFI" (C$,A(),B1(),B2(),C(,),D(,),DO$,MO,N$,R(,),S1$,TO$) ! JUL 87
105 !
110 ! This program dispatches control to the routines that allow
115 ! the user to edit test data and information. JUL 87
120 !
125 OPTION BASE 1@ DIM M$[80]
130 !
135 ! Have user select data to change.
140 !
145 SARRAY M$ @ SLET M$(1) = "Edit Header" @ SLET M$(2) = "Edit Range"
150 SLET M$(3) = "Edit Test Data" @ SLET M$(4) = "Edit Check Data"
155 SLET M$(6) = "Main Menu" @ CALL "MENU" ( 6,M$,R ) @ ON R GOTO 160,175,180,18
5,100,190
160 CALL "HEADER" ( C$,S1$,A(2),R(,),1,1,MO,TO$,DO$ ) @ WAIT 1500
165 CALL "HEADER" ( C$,S1$,A(2),R(,),2,0,MO,TO$,DO$ )
170 CALL "HEADER" ( C$,S1$,A(2),R(,),3,1,MO,TO$,DO$ ) @ GOTO 190
175 CALL "EDIT" ( R(,),D(,),B1(),N$,1 ) @ GOTO 190
180 CALL "EDIT" ( R(,),D(,),B1(),N$,2 ) @ GOTO 190
185 CALL "EDIT" ( R(,),C(,),B2(),N$,2 )
190 SCRATCHSUB "HEADER" @ SCRATCHSUB "EDIT" @ SUBEND
```

VAR	OCCURS IN LINE	
C $	100 ,160 ,165 ,170	test info from TOC (see main program xref)
A ( )	100 ,160 ,165 ,170	A(2)=no. of present range
B1(,)	100 ,175 ,180	readings/test point (see main program xref)
B2(,)	100 ,185	readings/check point(see main program xref)
C (,)	100 ,185	check meter data. (see main program xref)
D (,)	100 ,175 ,180	test meter data (see main program xref)
DO$	100 ,160 ,165 ,170	test date
MO	100 ,160 ,165 ,170	dummy variable
N $	100 ,175 ,180 ,185	dummy string
R (,)	100 ,160 ,165 ,170	array of range parameters (see main program
	175 ,180 ,185	xref)
S1$	100 ,160 ,165 ,170	present date
TO$	100 ,160 ,165 ,170	test and check meter info (see main program)
M $	125 ,145 ,145 ,145	array of strings of menu options
	150 ,150 ,155 ,155	
R	155 ,155	selected menu option

```
100 SUB "ENTER" (R(,),D(,),B1(),S(),N,K,A,B,X,Y,S,S1,S2,T1,T2,F1,R1)
105 !
110 ! "ENTER" computes fitted intercept a-hat, fitted slope b-hat,
115 ! standard deviation of readings s, goodness of fit F', intercept
120 ! test statistic t1 and slope test statistic t2 for the data
125 ! of the range or ranges that the user specifies. last modified
130 ! 6-30-87, 2:51.
135 !
140 ! INPUT: R(,)=ranges, D(,)=test or check data, B1()=no. of readings
145 ! at test points, S()=intermediate sums; OUTPUT: N=n, K=k,
150 ! A=a-hat, B=b-hat, X=av. ideal reading, Y=av. actual reading,
155 ! S=s, S1=S(a-hat), S2=S(b-hat), T1=t1, T2=t2, F1=F', R1=last
160 ! range specified
165 !
170 OPTION BASE 1@ DIM C1(10)
175 SCRATCHSUB "READAT"
180 !
185 ! store ranges to process in C1()
190 !
195 CLEAR @ CALL "QUERY" ( "Enter no. of ranges to combine.",R,L,Z$ )
200 IF L<1 OR L>8 THEN 195
205 ON R GOTO 210,195,405
210 FOR C=I TO L
215 CLEAR @ CALL "QUERY" ( "Enter range.",R,R1,Z$ )
220 IF R1<1 OR R1>8 THEN 215
225 ON R GOTO 230,215,405
230 IF R(R1,2)=0 THEN DISP "Data not present for range ";R1 ELSE GOTO 240
235 WAIT 2000 @ GOTO 195
240 C1(C)=R1 @ NEXT C
245 !
250 CLEAR @ DISP "Computation -- please wait."
255 ! FND(Z)=Z changed to values between -1 and 159 inclusive
260 DEF FND(Z) = Z-360*(Z>359 AND Z<361)
265 S(1),S(2),S(3),S(4),S(5),S(6),S(7),S(8),S(9),N,K=0
270 !
275 ! loop to find averages
280 !
285 ! S(1)=n Σx; S(2)=n Σx^2; x=ideal reading
290 ! S(3)= Σy; y=actual reading
295 FOR C=1 TO L @ R1=C1(C) @ FOR I=R(R1,1) TO R(R1+1,1)-1 @ K=K+1 @ FOR J=2 TO
B1(I)+1
300 S(1)=S(1)+D(I,1) @ S(2)=S(2)+D(I,1)*D(I,1) @ S(3)=S(3)+FND(D(I,J)) @ N=N+1 @
 NEXT J @ NEXT I
305 NEXT C @ X=S(1)/N @ Y=S(3)/N
310 !
315 ! loop to find b-hat and a-hat
320 !
325 ! S(4)= Σ(y-Y)(x-X); S(5)=n Σ(x-X)^2
330 ! S(6)=SSE= Σ[y-(av. x at point)]^2
335 FOR C=1 TO L @ R1=C1(C) @ FOR I=R(R1,1) TO R(R1+1,1)-1 @ FOR J=2 TO B1(I)+1
340 S(4)=S(4)+(FND(D(I,J))-Y)*(D(I,1)-X) @ S(5)=S(5)+(D(I,1)-X)^2
345 S(6)=S(6)+(FND(D(I,J))-D(I,8))^2 @ NEXT J @ NEXT I @ NEXT C @ B=S(4)/S(5) @
A=Y-B*X
```

```
350 !
355 ! loop to find SSR
360 !
365 ! S(7)=SSR= Σ[y-(fitted y)]^2
370 FOR C=1 TO L @ R1=C1(C) @ FOR I=R(R1,1) TO R(R1+1,1)-1 @ FOR J=2 TO B1(I)+1
375 S(7)=S(7)+(FND(D(I,J))-(A+B*D(I,1)))^2 @ NEXT J @ NEXT I @ NEXT C
380 !
385 ! compute s, S(a-hat), S(b-hat), t1, t2, F'
390 !
395 S=SQR(S(7)/(N-2))
400 S1=SQR(S(2)/(N*S(5)))*S @ S2=SQR(1/S(5))*S
405 T1=ABS(A/S1) @ T2=ABS((B-1)/S2) @ F1=ABS((N-K)/(K-2)*(S(7)-S(6))/S(6))
410 SUBEND
```

VAR	OCCURS IN LINE	
R (,)	100 ,230 ,295 ,295 335 ,335 ,370 ,370	array of range parameters. (see main program xref)
D (,)	100 ,300 ,300 ,300 300 ,340 ,340 ,340 345 ,345 ,375 ,375	test or check data. (see main program xref)
B1( )	100 ,295 ,335 ,370	readings/data point (see main program xref)
S ( )	100 ,265 ,265 ,265 265 ,265 ,265 ,265 265 ,265 ,300 ,300 300 ,300 ,300 ,300 305 ,305 ,340 ,340 340 ,340 ,345 ,345 345 ,345 ,375 ,375 395 ,400 ,400 ,400 405 ,405 ,405	array of intermediate sums. S(1)=nΣx; S(2)=nΣx^2 (x=ideal reading); S(3)=$\Sigma\Sigma$y (y=actual reading); S(4)=$\Sigma\Sigma$(y-Y)(x-X); S(5)=nΣ(x-X)^2; S(6)=SSE=$\Sigma\Sigma$[y-(av. x at point)]^2; S(7)=SSR=$\Sigma\Sigma$[y-(fitted y)]^2
N	100 ,265 ,300 ,300 305 ,305 ,395 ,400 405	nk (no. or readings at each test point times no. of test points)
K	100 ,265 ,295 ,295 405 ,405	no. of test points
A	100 ,345 ,375 ,405	$\hat{a}$ (fitted y-intercept)
B	100 ,345 ,345 ,375 405	$\hat{b}$ (fitted slope)
X	100 ,305 ,340 ,340 345	average ideal reading
Y	100 ,305 ,340 ,345	average actual reading
S	100 ,395 ,400 ,400	standard deviation
S1	100 ,400 ,405	S($\hat{a}$)
S2	100 ,400 ,405	S($\hat{b}$)
T1	100 ,405	t1
T2	100 ,405	t2
F1	100 ,405	F'
R1	100 ,215 ,220 ,220 230 ,230 ,240 ,295 295 ,295 ,335 ,335 335 ,370 ,370 ,370	range no.
C1()	170 ,240 ,295 ,335 370	list of range numbers to use in calculations
R	195 ,205 ,215 ,225	numerical value of user's request
L	195 ,200 ,200 ,210 295 ,335 ,370	no. of ranges to combine
Z $	195 ,215	dummy string
C	210 ,240 ,240 ,295 295 ,305 ,335 ,335 345 ,370 ,370 ,375	C1() subscript loop control
I	295 ,295 ,300 ,300 300 ,300 ,300 ,335 335 ,340 ,340 ,340 345 ,345 ,345 ,370 370 ,375 ,375 ,375	data point no. loop control
J	295 ,300 ,300 ,335 340 ,345 ,345 ,370 375 ,375	reading no. loop control

```
100 SUB "FIT" (C$,R(,),D(,),B1(),S1$,T0$,D0$,H1)
105 !
110 ! This program dispatches control to various programs that
115 ! analyze data.  JUL 87
120 !
125 OPTION BASE 1 ! JUL 07-87
130 SCRATCHSUB "READAT"
135 SCRATCHSUB "ENTER"
140 DIM S(10)
145 DIM M3$[109]
150 SARRAY M3$ @ GOTO 260
155 !
160 ! Allow user to select a function.
165 !
170 ALPHA 1 @ CLEAR
175 C=0 @ M=10
180 SLET M3$(1) = "Enter Range"
185 SLET M3$(3) = "Print Header"
190 SLET M3$(4) = "Print Par"
195 SLET M3$(5) = "Print Data"
200 SLET M3$(7) = "Reg. Est. "
205 SLET M3$(8) = "Sel. Est. "
210 SLET M3$(10) = "Main Menu"
215 CALL "MENU" ( M,M3$,C )
220 SCRATCHSUB "MENU"
225 SCRATCHSUB "DATA"
230 SCRATCHSUB "PLOT"
235 SCRATCHSUB "HEADER"
240 ON C GOTO 260,100,400,270,365,100,305,335,100,440
245 !
250 ! Enter range and calculate fit.
255 !
260 CALL "ENTER" ( R(,),D(,),B1(),S(),N,K,A,B,X,Y,S,S1,S2,T1,T2,F1,R1 )
265 SCRATCHSUB "ENTER" @ GOTO 170
270 DISP "Please wait..." @ GOSUB 420
275 CALL "STAT" ( S(),N,K,A,B,X,Y,S,S1,S2,T,T1,T2,F,F1,1 )
280 SCRATCHSUB "STAT"
285 GOTO 170
290 !
295 ! Print regular fit estimates of phase angle.
300 !
305 CALL "REG" ( A,B )
310 SCRATCHSUB "REG"
315 GOTO 170
320 !
325 ! Print fit estimates for selected phase angles.
330 !
335 CALL "SEL" ( A,B )
340 SCRATCHSUB "SEL"
345 GOTO 170
```

```
350 !
355 ! Print all data.
360 !
365 DISP "Please wait..." @ GOSUB 420
370 CALL "PDATA" ( R(,),D(,),B1(),A,B,R1 )
375 SCRATCHSUB "PDATA"
380 GOTO 170
385 !
390 ! Print the header.
395 !
400 GOSUB 420 @ GOTO 170
405 !
410 ! Routine to print the header.
415 !
420 CALL "HEADER" ( C$,S1$,R1,R(,),3,H1,M0,T0$,D0$ )
425 SCRATCHSUB "HEADER"
430 RETURN
435 !
440 SUBEND
```

VAR	OCCURS IN LINE	
C $	100 ,420	test info from TOC (see main program xref)
R (,)	100 ,260 ,370 ,420	range parameters (see main program xref)
D (,)	100 ,260 ,370	test or check data. (see main program xref)
B1(,)	100 ,260 ,370	readings/data point (see main program xref)
S1$	100 ,420	present date
T0$	100 ,420	test and check meter info (see main program)
D0$	100 ,420	test date
H1	100 ,420	set if fitting test data
S ()	140 ,260 ,275	intermediate sums. (see ENTER xref)
M3$	145 ,150 ,180 ,185 190 ,195 ,200 ,205 210 ,215	array of strings of menu options
C	175 ,215 ,240	selected menu option
M	175 ,215	no. of options in menu
N	260 ,275	nk (see ENTER xref)
K	260 ,275	no. of data points
A	260 ,275 ,305 ,335 370	$\hat{a}$ (fitted y-intercept)
B	260 ,275 ,305 ,335 370	$\hat{b}$ (fitted slope)
X	260 ,275	average ideal reading
Y	260 ,275	average actual reading
S	260 ,275	standard deviation
S1	260 ,275	$S(\hat{a})$
S2	260 ,275	$S(\hat{b})$
T1	260 ,275	t1
T2	260 ,275	t2
F1	260 ,275	F'
R1	260 ,370 ,420	range no.
T	275	Student's t
F	275	upper 1% point of F distribution
M0	420	dummy variable

```
100 SUB "F_TABL" (A,V1,V2,F)
105 !
110 ! This program calculates the F-statistic through a binary
115 ! search of table values figured in the INV_F program. JUL 87
120 !
125 ! INPUT: A=upper percent points; V1,V2=degrees of freedom in
130 ! numerator, denominator.  JUL 87
135 !
140 ! F1,F2=low, high approximations for F.
145 F1,F2=1
150 ! Find a too high approximation for F.
155 CALL "INV_F" ( F2,V1,V2,P ) @ IF P>A THEN F1=F2 @ F2=F2*2 @ GOTO 155
160 ! F=value halfway between the too high and too low values.
165 ! P=resultant % points.  If P is too low then F is too high,
170 ! so change too high value to F.  If P is too high then F
175 ! is too low, so change too low value to F.
180 F=(F1+F2)/2 @ CALL "INV_F" ( F,V1,V2,P ) @ IF P-A<-.001 THEN F2=F @ GOTO 180

185 IF P-A>.001 THEN F1=F @ GOTO 180
190 ! P is just right, within an accuracy of .001.
195 SCRATCHSUB "INV_F" @ SUBEND
```

VAR	OCCURS IN LINE	
A	100 ,155 ,180 ,185	upper percentage points
V1	100 ,155 ,180	degrees of freedom in numerator
V2	100 ,155 ,180	degrees of freedom in denominator
F	100 ,180 ,180 ,180 185	F-statistic
F1	145 ,155 ,180 ,185	low approximation for F
F2	145 ,155 ,155 ,155 155 ,180 ,180	high approximation for F
P	155 ,155 ,180 ,180 185	percentage points corresponding to F

```
100 SUB "GET_DATA" (R,B1(),B2(),T1,A1,A2,A3,F2,F3,I2$,I3$,P2,P3,S1$,D0$,Z)
105 !
110 ! "GET_DATA" initializes the standard phase meter to a given
115 ! range, optionally records auto-zero sample data, automatically
120 ! selects and sets the meter to each angle of the test, and
125 ! records the read or user-entered angles of the meters.  JUL 87
130 !
135 OPTION BASE 1
140 COM C$[60],R(10,4),C(100,8),D(100,8),A(5),T0$[100]
145 DIM I$[20]
150 !
155 ! Function to reduce voltage over 100 by factor of 40 to
160 ! compensate for the standard's step-up.
165 !
170 DEF FNV$(Q)
175 Q=ABS(R(R,Q)) @ IF Q>100 THEN Q=Q/40
180 FNV$=VAL$(Q) @ FN END
185 !
190 ! Function to keep angles within range of -1 to 359.
195 !
200 DEF FND(Q) = Q-360*(Q>359 AND Q<361)
205 !
210 ! Set the standard and the phase meters that are to be read
215 ! automatically.  Also display the range parameters for the
220 ! user to verify.
225 !
230 CLEAR @ IF FLAG(2) THEN OUTPUT A2 ;I2$
235 IF FLAG(3) THEN OUTPUT A3 ;I3$
240 CALL "TALK" ( A1,"LRC"&VAL$(R(R,4))&".DO"&FNV$(2)&".000D1"&FNV$(3)&".000CQDO
QD1Q",3 )
245 WAIT 4000
250 !
255 ! Allow user to take auto-zero samples.
260 !
265 CFLAG 5 @ CALL "A-ZERO" ( A1,A(2),D(,),0 )
270 SCRATCHSUB "A-ZERO" @ IF FLAG(5) THEN 720
275 !
280 ! Get ready to get phase meter data.
285 !
290 CALL "HEADER" ( C$,S1$,A(2),R(,),3,1,M0,T0$,D0$ ) @ SCRATCHSUB "HEADER"
295 ! A(4)=no. of readings already taken.
300 A(4)=0 @ FOR I=R(A(2),1) TO R(A(2)+1,1)-1 @ A(4)=A(4)+B1(I) @ NEXT I
305 ! S1=no. of test points in range, I1=last test point taken.
310 S1=R(A(2)+1,1)-R(A(2),1) @ I1=0
315 !
320 ! Head of loop to get phase meter data.
325 !
330 ! Increment no. of readings, and exit if average no. of
335 ! readings S2= wanted no. of readings.
340 A(4)=A(4)+1 @ S2=INT((A(4)-1)/S1) @ IF S2>=A(3) THEN Z=0 @ GOTO 725
345 ! Find a reading that hasn't been taken and doesn't repeat
```

```
350 ! the last angle. I is the test point of that reading.
355 I=IP(S1*RND)+R(A(2),1) @ IF B1(I)>S2 THEN 355
360 IF I=I1 THEN 355 ELSE I1=I
365 !
370 ! Show the present test point.
375 !
380 PRINT USING 390 ; I,B1(I),D(I,1),A(4)
385 CLEAR @ DISP S1$;"  ";TIME$ @ DISP USING 390 ; I,B1(I),D(I,1),A(4)-A(3)*S1
390 IMAGE "TEST PT",3D,"-",D,X,"PHASE",M3D.3D,2X,M2D
395 !
400 ! Set and retrieve phase angle.
405 !
410 CALL "TALK" ( A1,"A"&VAL$(D(I,1)+.0001)&"LRAQ",1 )
415 !
420 ! Wait for meter(s) to settle.
425 !
430 ON KYBD K,"A"&CHR$(128) GOTO 730 @ ON TIMER# 1,T1 GOTO 445
435 FOR T2=1 TO 180 @ WAIT 1000 @ BEEP 20,2
440 NEXT T2 @ DISP "Timing failure. Press <CONT>." @ PAUSE
445 OFF TIMER# 1 @ OFF KYBD
450 IF NOT FLAG(2) OR FLAG(1)>FLAG(3) THEN BEEP 100,80 @ BEEP 50,80 @ BEEP 25,10
0
455 !
460 ! Get automatic readings.
465 !
470 IF FLAG(2) THEN A=A2 @ F=F2 @ P=P2 @ Z$="TEST" @ GOSUB 675 @ D2=Q
475 IF FLAG(3) THEN A=A3 @ F=F3 @ P=P3 @ Z$="CHECK" @ GOSUB 675 @ D3=Q
480 !
485 ! Get test meter reading from user.
490 !
495 IF FLAG(2) THEN 535
500 CALL "QUERY" ( "Enter test data.",R,D2,Z$ )
505 IF Z$[1,1]="A" THEN 730
510 ON R GOTO 515,495,720
515 Q=D2 @ GOSUB 760 @ ON Y GOTO 500,535,720
520 !
525 ! Store test reading and new average, and update reading count.
530 !
535 D(I,B1(I)+2)=D2 @ Q=0
540 FOR K=2 TO 7 @ Q=Q+FND(D(I,K)) @ NEXT K
545 B1(I)=B1(I)+1 @ D(I,8)=Q/B1(I)
550 !
555 ! Get check meter reading.
560 !
565 IF NOT FLAG(1) THEN 340
570 IF FLAG(3) THEN 635
575 CALL "QUERY" ( "Enter check data.",R,D3,Z$ )
580 IF Z$[1,1]<>"A" THEN 610
585 ! Erase last test point so that test and check data will correspond.
590 B1(I)=B1(I)-1 @ D(I,B1(I)+2)=0
595 IF NOT B1(I) THEN D(I,8)=0 @ GOTO 730
600 Q=Q+FND(D(I,K)) @ NEXT K
```

```
605 D(I,8)=Q/B1(I) @ GOTO 730
610 ON R GOTO 615,575,720
615 Q=D3 @ GOSUB 760 @ ON Y GOTO 575,635,720
620 !
625 ! Store check reading and new average, and update reading count.
630 !
635 C(I,B2(I)+2)=D3 @ Q=0
640 FOR K=2 TO 7 @ Q=Q+FND(C(I,K)) @ NEXT K
645 B2(I)=B2(I)+1 @ C(I,8)=Q/B2(I) @ GOTO 340
650 !
655 ! This routine reads a meter and returns the result in Q.
660 ! It is internal to avoid the delay caused by the initial
665 ! the initial loading of a CALLed program.
670 !
675 SET TIMEOUT 7;5000 @ ON TIMEOUT 7 GOTO 695
680 ENTER A ; Z$@ Q=VAL(Z$[P])*F
685 IF ABS(FND(Q)-D(I,1))>1 THEN PRINT "  **** INCONSISTENT DATA ****"
690 RETURN
695 CLEAR @ DISP "No response from ";Z$;" meter."
700 DISP 70,100 @ BEEP 100,150 @ BEEP 70,150
705 DISP @ DISP "Do you want to try again?"
710 CALL "YESNO" ( Y ) @ ON Y GOTO 675,720,720
715 !
720 Z=1
725 SCRATCHSUB "TALK" @ SUBEXIT
730 IF K=128 THEN 720
735 SCRATCHSUB "TALK" @ CALL "A-ZERO" ( A1,2,D(,),1 )
740 SCRATCHSUB "A-ZERO" @ IF FLAG(5) THEN 720 ELSE 385
745 !
750 ! This routine checks to see whether the data is consistent.
755 !
760 IF ABS(FND(Q)-D(I,1))<=1 THEN Y=2 @ RETURN
765 BEEP 70,100 @ BEEP 100,150 @ BEEP 70,150
770 DISP @ DISP "The data is inconsistent." @ DISP
775 DISP "Do you want to change the data?" @ CALL "YESNO" ( Y )
780 IF Y=2 THEN 685 ELSE DISP @ RETURN
```

VAR	OCCURS IN LINE	
R	100 ,175 ,240 ,500 510 ,575 ,610	no. of range to fill
B1(,)	100 ,300 ,355 ,380 385 ,535 ,545 ,545 545 ,590 ,590 ,590 595 ,605	no. of readings at each point of test meter
B2(,)	100 ,635 ,645 ,645 645	no. of readings at each point of check meter
T1	100 ,430	WAIT between readings
A1	100 ,240 ,265 ,410 735	bus address of phase standard
A2	100 ,230 ,470	bus address of test meter
A3	100 ,235 ,475	bus address of check meter
F2	100 ,470	test meter automatic reading multiplier
F3	100 ,475	check meter automatic reading multiplier
I2$	100 ,230	instructions to setup test meter for auto reading
I3$	100 ,235	instructions to setup check meter for auto reading
P2	100 ,470	position of reading in test meter input
P3	100 ,475	position of reading in check meter input
S1$	100 ,290 ,385	present date
D0$	100 ,290	date of test
Z	100 ,340 ,720	set when aborting to main menu
C $	140 ,290	test info from TOC (see main program xref)
R (,)	140 ,175 ,240 ,290 300 ,300 ,310 ,310 355	array of range parameters (see main program xref)
C (,)	140 ,635 ,640 ,645	check meter data. (see main program xref)
D (,)	140 ,265 ,380 ,385 410 ,535 ,540 ,545 590 ,595 ,600 ,605 685 ,735 ,760	test meter data. (see main program xref)
A ( )	140 ,265 ,290 ,300 300 ,300 ,300 ,300 310 ,310 ,340 ,340 340 ,340 ,355 ,380 385 ,385	A(1)=next available test point; A(2)=present range; A(3)=no. of readings to take; A(4)=reading on.
T0$	140 ,290	test and check meter info (see main program xref)
I $	145	unused
M0	290	dummy variable
I	300 ,300 ,300 ,355 355 ,360 ,360 ,380 380 ,380 ,385 ,385 385 ,410 ,535 ,535 540 ,545 ,545 ,545 545 ,590 ,590 ,590 590 ,595 ,595 ,600 605 ,605 ,635 ,635 640 ,645 ,645 ,645 645 ,685 ,760	no. of data point being taken
S1	310 ,340 ,355 ,385	no. of test points in range
I1	310 ,360 ,360	last test point taken
S2	340 ,340 ,355	average no. of readings taken in each data point
K	430 ,540 ,540 ,540 600 ,600 ,640 ,640 640 ,730	multi-purpose variable. contains value of interrupting programmed key. also is a loop control
T2	435 ,440	loop control for ticking during wait between readings
A	470 ,475 ,680	bus address of test or check meter
F	470 ,475 ,680	reading multiplier for test or check meter
P	470 ,475 ,680	position of reading in test or check meter input
Z $	470 ,475 ,500 ,505 575 ,580 ,680 ,680 695	multi-purpose variable.
D2	470 ,500 ,515 ,535	test meter reading
Q	470 ,475 ,515 ,535 540 ,540 ,545 ,600 600 ,605 ,615 ,635 640 ,640 ,645 ,680 685 ,760	multi-purpose variable. contains test or check meter reading. also is sum of readings at a test point.
D3	475 ,575 ,615 ,635	check meter reading
Y	515 ,615 ,710 ,710 760 ,775 ,780	multi-purpose variable. numerical value of user's request. also describes action to take on encountering inconsistent data

BEST COPY AVAILABLE

```
100 SUB "GET_PARAMS" (R,A(),T1,TO$,A1,A2,A3,F2,F3,I2$,I3$,P2,P3)
105 !
110 ! This program prompts the user for the parameters needed
115 ! to conduct a test and take data.  JUL 87
120 !
125 ! INPUT: TO$()=test and check meter info; OUTPUT: R,A(2)=range
130 ! to fill; A(3)=readings/point; T1=WAIT time between readings;
135 ! A1,A2,A3=bus address for standard, test meter, check meter;
140 ! F2,F3=factor by which automatic meter readings are multiplied;
145 ! I2$,I3$=instruction code to query test, check meter; P2,P3=
150 ! byte of beginning of reading in string returned by test,
155 ! check meter; FLAG(2),FLAG(3)=1 if test, check meter is to
160 ! be read; FLAG(5)=1 if user requests main menu.
165 !
170 OPTION BASE 1@ DIM I$[20],M$[400]
175 INTEGER F(10),L(10)
180 !
185 CLEAR @ DISP "Enter range you want to fill."
190 CALL "QUERY" ( " Range "&VAL$(A(2))&" is the default.",R,Z,Z$ )
195 ON R GOTO 200,210,565
200 A(2)=Z @ IF Z<1 OR Z>8 THEN A(2)=1 @ GOTO 185
205 !
210 CLEAR @ R=A(2) @ IF A(3)=0 THEN A(3)=4
215 DISP "Specify 1 to 6 readings per"
220 CALL "QUERY" ( " testpoint. "&VAL$(A(3))&" is the default.",Y,Z,Z$ )
225 DISP @ ON Y GOTO 230,240,565
230 IF Z<1 OR Z>6 THEN 215 ELSE A(3)=Z
235 !
240 T1=20 @ DISP "Specify wait of at least 2"
245 CALL "QUERY" ( " seconds.  20 is the default.",Y,T1,Z$ )
247 ON Y GOTO 250,250,565
250 IF T1<2 THEN 240 ELSE T1=T1*1000-1999
255 !
260 ! Get meter query instructions from disk.
265 !
270 ON ERROR GOTO 285 @ ASSIGN# 1 TO "METERS:D700" @ OFF ERROR
275 READ# 1 ; N,M$,F(),L()@ GOTO 300
280 ! The file doesn't exist yet, so make it.
285 OFF ERROR @ CREATE "METERS·D700",3,256
290 FOR I=1 TO 10 @ F(I),L(I)=1 @ NEXT I @ M$[400]=" " @ N=0
295 ASSIGN# 1 TO "METERS:D700" @ PRINT# 1 ; N,M$,F(),L()
300 ASSIGN# 1 TO *
305 !
310 ! Get bus addresses from user and see if readings are to be
315 ! taken via bus. If user wants automatic reading then see
320 ! whether the querying instructions for the meter(s) is(are)
325 ! already stored on disk. If not then get the info and add
330 ! it to the METERS file.
335 !
340 CLEAR @ DISP "Enter address of PHASE STANDARD."
345 A1=1 @ CALL "QUERY" ( " 1 is the default.",Y,A1,Z$ )
347 ON Y GOTO 350,350,565
350 A1=A1+716 @ IF A1<717 OR A1>731 THEN 340
```

```
355 ! Initialize FLAGs. 2 and 3 are described at the beginning of
360 ! this program. 4 will be set by end of prompts if additions
365 ! are made to the meter info file.
370 CFLAG 2 @ CFLAG 3 @ CFLAG 4
372 A2,A,M,P=0
375 F=2 @ I$="TEST" @ GOSUB 430 @ A2=A @ F2=M @ I2$=I$ @ P2=P
380 ! FLAG(1)=1 if test will use a check meter.
385 IF FLAG(1) THEN F=3 @ I$="CHECK" @ GOSUB 430 @ A3=A @ F3=M @ I3$=I$ @ P3=P
390 !
395 ! Save additions to METERS, if any.
400 !
405 IF FLAG(4) THEN ASSIGN# 1 TO "METERS:D700" @ PRINT# 1 ; N,M$,F(),L() @ ASSIG
N# 1 TO *
410 CFLAG 5 @ SUBEXIT
415 !
420 ! This info gathering routine is called once per meter.
425 !
430 CLEAR @ DISP "Do you want the "&I$&" meter to" @ DISP " be read via bus?"
435 SFLAG F @ CALL "YESNO" ( Y ) @ ON Y GOTO 445,440,565
440 CFLAG F @ RETURN
445 !
450 CLEAR @ CALL "QUERY" ( "Enter address of "&I$&" meter.",Y,A,Z$ )
455 ON Y GOTO 460,450,565
460 A=A+700 @ IF A<700 OR A>731 OR A=A1-16 OR A=A2 THEN 450
465 ! See whether METERS already has info about this meter.
470 I=F*3-5 @ I$[1,10]=GET$(TO$(I)) @ I$[11,20]=GET$(TO$(I+1))
475 FOR L=1 TO 361 STEP 40 @ IF M$[L,L+19]=I$ THEN 545
480 NEXT L
485 ! Meter not found. Prompt user for info.
490 DISP @ CALL "QUERY" ( "Enter the instruction code for   setting up this mete
r.",Y,Z,I$ )
495 ON Y GOTO 500,490,565
500 DISP @ DISP "At which byte of the returned"
505 CALL "QUERY" ( " string does the reading begin?",Y,P,Z$ )
510 ON Y GOTO 515,500,565
515 DISP @ DISP "By what factor must the reading" @ M=1
520 CALL "QUERY" ( " be adjusted. 1 is the default.",Y,M,Z$ )
525 ON Y GOTO 530,530,565
530 L=N*40+1 @ N=N+1 @ F(N)=M @ L(N)=P @ M$[L,L+9]=GET$(TO$(I))
535 M$[L+10,L+19]=GET$(TO$(I+1)) @ M$[L+20,L+39]=I$ @ SFLAG 4 @ RETURN
540 ! Meter found. Copy info.
545 FOR I=L+39 TO L+20 STEP -1 @ IF M$[I,I]<>" " THEN 555
550 NEXT I
555 I$=M$[L+20,I] @ I=INT(L-1)/40+1 @ M=F(I) @ P=L(I) @ RETURN
560 !
565 SFLAG 5 @ SUBEND
```

VAR	OCCURS IN LINE	
R	100 ,190 ,195 ,210	no. of range to fill
A ( )	100 ,190 ,200 ,200 210 ,210 ,210 ,220 230	A(2)=present range; A(3)=no. of readings to take
T1	100 ,240 ,245 ,250 250 ,250	WAIT between readings
T0$	100 ,470 ,470 ,530 535	test and check meter info (see main program xref)
A1	100 ,345 ,345 ,350 350 ,350 ,350 ,460	bus address of phase standard
A2	100 ,372 ,375 ,460	bus address of test meter
A3	100 ,385	bus address of check meter
F2	100 ,375	test meter automatic reading multiplier
F3	100 ,385	check meter automatic reading multiplier
I2$	100 ,375	instructions to set up test meter
I3$	100 ,385	instructions to set up check meter
P2	100 ,375	position of reading in test meter input
P3	100 ,385	position of reading in check meter input
I $	170 ,375 ,375 ,385 385 ,430 ,450 ,470 470 ,475 ,490 ,535 555	multi-purpose string. initially contains the type of meter being set up. returning from the routine at line 420 it contains the instructions to set up the given meter.
M $	170 ,275 ,290 ,295 405 ,475 ,530 ,535 535 ,545 ,555	meter information string. M$[o,o+9]=manufacturer; M$[o+10,o+19]=model no.; M$[o+20,o+39]=instruction string to set up meter
F ()	175 ,275 ,290 ,295 405 ,530 ,555	array of automatic reading multipliers -- gives multiplier for each meter in METERS file
L ()	175 ,275 ,290 ,295 405 ,530 ,555	array of positions of readings in meter input -- gives position for each meter in METERS file
Z	190 ,200 ,200 ,200 220 ,230 ,230 ,230 490	user's numerical input
Z $	190 ,220 ,245 ,345 450 ,505 ,520	dummy string
Y	220 ,225 ,245 ,247 345 ,347 ,435 ,435 450 ,455 ,490 ,495 505 ,510 ,520 ,525	numerical value of user's request
N	275 ,290 ,295 ,405 530 ,530 ,530 ,530 530	number of meters in the METERS file
I	290 ,290 ,290 ,290 470 ,470 ,470 ,530 535 ,545 ,545 ,545 550 ,555 ,555 ,555 555	multi-purpose variable. serves as loop control, and in lines 470, 530, and 535, as an index into the T0$() array
A	372 ,375 ,385 ,450 460 ,460 ,460 ,460 460 ,460	address of meter to be considered in the routine at line 420
M	372 ,375 ,385 ,515 520 ,530 ,555	test or check meter reading multiplier, used to adjust readings that are taken via bus
P	372 ,375 ,385 ,505 530 ,555	[illegible]tion of reading in test or check meter input
F	375 ,385 ,435 ,440 470	[illegible]ag to set if meter considered by routine at line 420 is to be read automatically
L	475 ,475 ,475 ,480 530 ,530 ,530 ,535 535 ,535 ,535 ,545 545 ,555 ,555	location in M$ of information about meter being considered

BEST COPY AVAILABLE

```
100 SUB "GETRNG" (A(),C(,),D(,),R(,),B1(),B2())
105 !
110 ! This program initializes ranges and ideal readings for
115 ! their data.  AUG 87
120 !
125 ! Determine range to set up.
130 !
135 OPTION BASE 1
140 !
145 ! Find a free range, if any.
150 A(2)=0 @ IF R(1,1)=0 THEN A(1)=1
155 IF A(2)=8 THEN CLEAR @ DISP "No free ranges." @ WAIT 2000 @ SUBEXIT
160 A(2)=A(2)+1 @ IF R(A(2),2)<>0 THEN 155
165 A(1)=R(A(2),1)
170 ! Automatically use range 1 if no ranges have been used.
175 IF A(2)=1 THEN GOTO 265
180 ! See if user wants to restart a range.
185 CLEAR @ DISP "Enter range to setup."
190 CALL "QUERY" ( " Range "&VAL$(A(2))&" is the default.",Y,R,Z$ )
195 ON Y GOTO 200,265,440
200 IF R<1 OR R>8 THEN 185
205 A(2)=R @ A(1)=R(A(2),1)
210 ! Parameters can be changed without changing readings.
215 DISP @ DISP "Do you want to discard old data?"
220 CALL "YESNO" ( R ) @ ON R GOTO 230,150,440
225 ! zero test points of range
230 FOR J=R(A(2),1) TO R(A(2)+1,1)-1
235 B1(J),B2(J)=0
240 FOR K=2 TO 8 @ D(J,K),C(J,K)=0 @ NEXT K @ NEXT J
245 SUBEND
250 !
255 ! Prompt user for parameters.
260 !
265 CLEAR @ DISP "PARAMETERS FOR RANGE";A(2)
270 DISP @ CALL "QUERY" ( "Enter reference channel.",R,R1,Z$ )
275 ON R GOTO 280,265,440
280 DISP @ CALL "QUERY" ( "Enter variable channel.",R,V1,Z$ )
285 ON R GOTO 290,280,440
290 DISP @ CALL "QUERY" ( "Enter frequency.",R,F1,Z$ )
295 ON R GOTO 300,290,440
300 R(A(2),2)=R1 @ R(A(2),3)=V1 @ R(A(2),4)=F1 @ R(A(2),1)=A(1)
305 CLEAR @ DISP "Do you want to test points at   regular intervals?"
310 CALL "YESNO" ( Y ) @ ON Y GOTO 315,390,440
315 CLEAR @ CALL "QUERY" ( "Enter starting phase angle.",R,S,Z$ )
320 ON R GOTO 325,315,440
325 DISP @ CALL "QUERY" ( "Enter ending phase angle.",R,E,Z$ )
330 ON R GOTO 335,325,440
335 DISP @ CALL "QUERY" ( "Enter angle increment.",R,I,Z$ )
340 ON R GOTO 345,335,440
345 NO=A(1)+INT((E-S)/I)+1 @ IF NO>91 THEN A(1)=92 @ GOSUB 435
```

```
350 !
355 ! Automatically set ideal readings.
360 !
365 FOR N=S TO E STEP I @ D(A(1),1)=S @ C(A(1),1)=S @ S=S+I
370 A(1)=A(1)+1 @ R(A(2)+1,1)=A(1) @ NEXT N @ GOTO 440
375 !
380 ! Manually set ideal readings.
385 !
390 CLEAR @ DISP "Enter phase angle, N (new range) or E (end)."
395 DISP A(1) @ CALL "QUERY" ( "",R,Z,S$ ) @ ON R GOTO 405,395,440
400 A(2)=A(2)+1 @ GOTO 175
405 IF S$[1,1]="E" THEN 440
410 GOSUB 435 @ D(A(1),1)=VAL(S$) @ C(A(1),1)=VAL(S$)
415 A(1)=A(1)+1 @ R(A(2)+1,1)=A(1) @ GOTO 395
420 !
425 ! Abort range entry if has too many test points.
430 !
435 CALL "CHKRNG" ( Z,A(),R(,) ) @ IF Z THEN RETURN
440 SCRATCHSUB "CHKRNG" @ SUBEXIT
```

VAR	OCCURS IN LINE	
A ( )	100 ,150 ,150 ,155	A(1)=next available test point; A(2)=present range no.
	160 ,160 ,160 ,165	
	165 ,175 ,190 ,205	
	205 ,205 ,230 ,230	
	265 ,300 ,300 ,300	
	300 ,300 ,345 ,345	
	365 ,365 ,370 ,370	
	370 ,370 ,395 ,400	
	400 ,410 ,410 ,415	
	415 ,415 ,415 ,435	
C (,)	100 ,240 ,365 ,410	check meter data. (see main program xref)
D (,)	100 ,240 ,365 ,410	test meter data. (see main program xref)
R (,)	100 ,150 ,160 ,165	array of range parameters (see main program xref)
	205 ,230 ,230 ,300	
	300 ,300 ,300 ,370	
	415 ,435	
B1( )	100 ,235	no. of readings at each point of test meter
B2( )	100 ,235	no. of readings at each point of check meter
Y	190 ,195 ,310 ,310	information about user's request
R	190 ,200 ,200 ,205	no. of range to set up
	220 ,220 ,270 ,275	
	280 ,285 ,290 ,295	
	315 ,320 ,325 ,330	
	335 ,340 ,395 ,395	
Z $	190 ,270 ,280 ,290	dummy string
	315 ,325 ,335	
J	230 ,235 ,235 ,240	data point no. loop control
	240 ,240	
K	240 ,240 ,240 ,240	reading no. loop control
R1	270 ,300	reference channel voltage (see main program)
V1	280 ,300	variable channel voltage (see main program)
F1	290 ,300	frequency
S	315 ,345 ,365 ,365	starting phase angle
	365 ,365 ,365	
E	325 ,345 ,365	ending phase angle
I	335 ,345 ,365 ,365	angle increment
NO	345 ,345	estimated last data point in range
N	365 ,370	phase angle loop control
Z	395 ,435 ,435	dummy variable and return to menu flag
S $	395 ,405 ,410 ,410	user's reply to query

```
100 SUB "HEADER" (C$,S1$,R1,R(,),N0,N1,M0,T0$,D0$)
105 !
110 ! This program handles all header interaction.  On entry,
115 ! N0=1 to edit the test meter header, 2 to edit the check
120 ! meter header, and 3 to print the existing headers.  AUG 87
125 !
130 OPTION BASE 1
135 DIM P$[75],Z$[30]
140 SARRAY P$
145 SLET P$(1) = "Manufacturer "
150 SLET P$(2) = "Model #"
155 SLET P$(3) = "Serial #"
160 SLET P$(4) = "Enter "
165 SLET P$(5) = "Test Date "
170 ON N0 GOTO 175,180,400
175 I=0 @ GOTO 200
180 I=3
185 !
190 ! Edit the test or check meter header.
195 !
200 ON ERROR GOTO 210
205 IF D0$<>"" THEN 215
210 OFF ERROR @ D0$=S1$
215 CLEAR @ IF I=3 THEN DISP "Check Standard Data:" ELSE DISP "Test Instrument D
ata:"
220 ! Show the header.
225 DISP @ IF NOT I THEN DISP C$[1,30] @ DISP @ DISP "Folder #: ";C$[51,60]
230 DISP GET$(P$(5));D0$
235 FOR K=1 TO 3
240 DISP GET$(P$(K));GET$(T0$(K+I)) @ NEXT K
245 DISP @ DISP "Is the information correct?" @ CALL "YESNO" ( R ) @ ON R GOTO 3
80,255,375
250 ! Get the customer.
255 IF I THEN 300 ELSE Z$=C$[1,30] @ GOSUB 510
260 CALL "QUERY" ( "Enter customer.",R,Z,Z$ )
265 ON R GOTO 270,280,375
270 C$[1,30]=Z$
275 ! Get the folder #.
280 Z$=C$[51,60] @ GOSUB 510 @ CALL "QUERY" ( "Enter folder #.",R,Z,Z$ )
285 ON R GOTO 290,300,375
290 C$[51,60]=Z$
295 ! Get the test date.
300 Z$=D0$ @ GOSUB 510 @ CALL "QUERY" ( GET$(P$(4))&GET$(P$(5)),R,Z,Z$ )
305 ON R GOTO 310,320,375
310 D0$=Z$
315 ! Get the manufacturer.
320 Z$=GET$(T0$(I+1)) @ GOSUB 510 @ CALL "QUERY" ( GET$(P$(4))&GET$(P$(1)),R,Z,T
9$ )
325 ON R GOTO 330,340,375
330 SLET T0$(I+1) = T9$
335 ! Get the model #.
340 Z$=GET$(T0$(I+2)) @ GOSUB 510 @ CALL "QUERY" ( GET$(P$(4))&GET$(P$(2)),R,Z,T
9$ )
345 ON R GOTO 350,360,375
350 SLET T0$(I+2) = T9$
```

```
355 ! Get the serial #.
360 Z$=GET$(TO$(I+3)) @ GOSUB 510 @ CALL "QUERY" ( GET$(P$(4))&GET$(P$(3)),R,Z,T
9$ )
365 ON R GOTO 370,215,375
370 SLET TO$(I+3) = T9$ @ GOTO 215
375 MO=1 @ SUBEXIT
380 MO=0 @ SUBEXIT
385 !
390 ! Print the header.
395 !
400 IF N1 THEN I1$=CHR$(0)&" " @ I2$="  " ELSE I1$="  " @ I2$=CHR$(0)&" "
405 PRINT @ PRINT @ PRINT
410 PRINT S1$;"         ";TIME$
415 PRINT GET$(P$(5))&DO$
420 PRINT @ PRINT C$[1,30] @ PRINT
425 IF GET$(TO$(1))=" " THEN 445
430 PRINT @ PRINT I1$;GET$(TO$(1))
435 PRINT TAB(4);GET$(P$(2));GET$(TO$(2))
440 PRINT TAB(4);GET$(P$(3));GET$(TO$(3))
445 IF GET$(TO$(4))=" " THEN 465
450 PRINT @ PRINT I2$;GET$(TO$(4))
455 PRINT TAB(4);GET$(P$(2));GET$(TO$(5))
460 PRINT TAB(4);GET$(P$(3));GET$(TO$(6))
465 PRINT @ PRINT @ IF R1>0 THEN PRINT "RANGE";R1 ELSE SUBEND
470 V$="Voltage:"
475 I$="Current:"
480 IF R(R1,2)<0 THEN X$=I$ ELSE X$=V$
485 IF R(R1,3)<0 THEN Y$=I$ ELSE Y$=V$
490 PRINT USING 495 ; X$,ABS(R(R1,2)),Y$,ABS(R(R1,3)),R(R1,4)
495 IMAGE "Reference ",8A,3D.2D/"Variable  ",8A,3D.2D/"Frequency:",7X,5D
500 PRINT @ PRINT
505 SUBEND
510 CLEAR @ ON ERROR GOTO 520
515 IF Z$[1,2]<>"  " THEN DISP "No input implies ";Z$ @ DISP
520 OFF ERROR @ RETURN
```

```
VAR     OCCURS IN LINE
C $     100 ,225 ,225 ,255      test info from TOC (see main program xref)
        270 ,280 ,290 ,420
S1$     100 ,210 ,410           present date
R1      100 ,465 ,465 ,480      range no. (used when printing the header)
        485 ,490 ,490 ,490
R (,)   100 ,480 ,485 ,490      array of range parameters (see main program
        490 ,490                  xref)
NO      100 ,170                tells program what to do (see lines 110-120)
N1      100 ,400                set if printout should point to check meter
MO      100 ,375 ,380           set if user requests an abort to main menu
TO$     100 ,240 ,320 ,330      test and check meter information (see main
        340 ,350 ,360 ,370        program xref)
        425 ,430 ,435 ,440
        445 ,450 ,455 ,460
DO$     100 ,205 ,210 ,230      date of test
        300 ,310 ,415
P $     135 ,140 ,145 ,150      array of strings of menu options
        155 ,160 ,165 ,230
        240 ,300 ,300 ,320
        320 ,340 ,340 ,360
        360 ,415 ,435 ,440
        455 ,460
Z $     135 ,255 ,260 ,270      user's input
        280 ,280 ,290 ,300
        300 ,310 ,320 ,340
        360 ,515 ,515
I       175 ,180 ,215 ,225      offset into TO$() used  to point to either
        240 ,255 ,320 ,330        the test or the check meter information
        340 ,350 ,360 ,370
K       235 ,240 ,240 ,240      loop control
R       245 ,245 ,260 ,265      information about user's request (see QUERY
        280 ,285 ,300 ,305        xref)
        320 ,325 ,340 ,345
        360 ,365
Z       260 ,280 ,300 ,320      dummy variable
        340 ,360
T9$     320 ,330 ,340 ,350      user's input
        360 ,370
I1$     400 ,400 ,430           space pads or points to test meter in printout
I2$     400 ,400 ,450           space pads or points to check meter in printout
V $     470 ,480 ,485           contains "Voltage:"
I $     475 ,480 ,485           contains "Current:"
X $     480 ,480 ,490           reference channel units
Y $     485 ,485 ,490           variable channel units
```

```
100 SUB "INITAR" (A(),B1(),B2(),C(,),D(,),R(,),TO$)
105 !
110 ! This program initializes all data arrays to zero.  JUL 87
115 !
120 OPTION BASE 1@ CLEAR @ DISP "Program is being initialized."
125 FOR I=1 TO 6 @ SLET TO$(I) = " " @ NEXT I
130 FOR I=1 TO 100 @ B1(I)=0 @ B2(I)=0 @ NEXT I @ FOR I=1 TO 5 @ A(I)=0 @ NEXT I

135 CALL "ZERO" ( "ranges",10,4,R(,) ) @ CALL "ZERO" ( "test data",100,8,D(,) )
140 CALL "ZERO" ( "check data",100,8,C(,) ) @ SCRATCHSUB "ZERO"
145 BEEP 70,100 @ BEEP 85,150
150 DISP "Initialization completed." @ WAIT 1500 @ SUBEND
```

VAR	OCCURS IN LINE	
A ( )	100 ,130	test info array (see main program xref)
B1( )	100 ,130	no. of readings at each point of test meter
B2( )	100 ,130	no. of readings at each point of check meter
C (,)	100 ,140	check meter data. (see main program xref)
D (,)	100 ,135	test meter data. (see main program xref)
R (,)	100 ,135	range parameters. (see main program xref)
TO$	100 ,125	test and check meter info (see main program)
I	125 ,125 ,125 ,130	loop control
	130 ,130 ,130 ,130	
	130 ,130	

```
360 SUB "INV_F" (F,V1,V2,P)
361 !
362 ! This program calculates the upper % points for the F
363 ! statistic F with degrees of freedom V1 in the numerator
364 ! and V2 in the denominator.
365 X=1/(V1/V2*F+1) @ Y=1-X @ P1,P2=1 @ U1=V1 @ U2=V2
370 IF V1 MOD 2#( THEN 372 ELSE 375
372 IF V2 MOD 2=0 THEN 390 ELSE 400
375 IF V2 MOD 2=0 THEN 377 ELSE 380
377 IF V2>=V1 THEN 390
380 FOR Z=1 TO V1/2-1 @ P1=P1*(.5/Z*Y*U2) @ P2=P2+P1 @ U2=U2+2 @ NEXT Z
385 P=X^(V2*.5)*P2 @ GOTO 450
390 FOR Z=1 TO V2/2-1 @ P1=P1*(.5/Z*X*U1) @ P2=P2+P1 @ U1=U1+2 @ NEXT Z
395 P=1-Y^(V1*.5)*P2 @ GOTO 450
400 X2=ATN(SQR(F*V1/V2)) @ X=SIN(X2) @ Y=COS(X2) @ P2=Y @ P1=Y
405 IF V2=1 THEN 420
410 FOR Z=2 TO V2-3 STEP 2 @ P1=P1*Y*Y*Z/(Z+1) @ P2=P2+P1 @ NEXT Z
415 P2=P2*X @ X2=X2+P2
420 P2=1 @ P1=1 @ IF V1=1 THEN 445
425 FOR Z=2 TO V2-1 STEP 2 @ P1=P1*Z/(Z-1) @ NEXT Z
430 P1=P1*Y^V2*X @ P3,P2=1 @ U2=V2+1
435 FOR Z=3 TO V1-2 STEP 2 @ P3=P3*U2*X*X/Z @ P2=P2+P3 @ U2=U2+2 @ NEXT Z
440 X2=X2-P2*P1
445 P=1-X2*2/PI
450 REM
455 ! PRINT P
460 SUBEND
```

VAR	OCCURS IN LINE	
F	360 ,365 ,400	F statistic
V1	360 ,365 ,365 ,370	degrees of freedom in numerator
	377 ,380 ,395 ,400	
	420 ,435	
V2	360 ,365 ,365 ,372	degrees of freedom in denominator
	375 ,377 ,385 ,390	
	400 ,405 ,410 ,425	
	430 ,430	
P	360 ,385 ,395 ,445	upper percentage points
X	365 ,365 ,385 ,390	
	400 ,415 ,430 ,435	
	435	
Y	365 ,380 ,395 ,400	
	400 ,400 ,410 ,410	
	430	
P1	365 ,380 ,380 ,380	
	390 ,390 ,390 ,400	
	410 ,410 ,410 ,420	
	425 ,425 ,430 ,430	
	440	
P2	365 ,380 ,380 ,385	
	390 ,390 ,395 ,400	
	410 ,410 ,415 ,415	
	415 ,420 ,430 ,435	
	435 ,440	
U1	365 ,390 ,390 ,390	
U2	365 ,380 ,380 ,380	
	430 ,435 ,435 ,435	
Z	380 ,380 ,380 ,390	
	390 ,390 ,410 ,410	
	410 ,410 ,425 ,425	
	425 ,425 ,435 ,435	
	435	
X2	400 ;400 ,400 ,415	
	415 ,440 ,440 ,445	
P3	430 ,435 ,435 ,435	

```
100 SUB "INV_T" (F,T,P)
105 !
110 ! This program calculates the Student's T statistic for P
115 ! % points with F degrees of freedom.
120 !
125 ! from TECHNOMETRICS Vol.8, No.2, May 1964, "Approximation
130 ! to the Cumulative t-Distribution" by C.Y. Kramer.
135 !
140 ! DISP USING "2A,4X,A,5X,A" ; "df","t",""
145 C1=.503226 @ D1=-.06082
150 C2=-.044928 @ D2=.585243
155 C3=.112057 @ D3=-.208977
160 C4=1.94979 @ D4=.025489
165 C5=-5.917356 @ D5=.082228
170 C6=-7.549051 @ D6=-.276747
175 C7=11.311627 @ D7=.080726
180 C8=-.399205 @ D8=.011192
185 C9=5.48717
190 IF T<2 THEN 200
195 P=C1+C2/F+C3/F^2+C4/(F*T^2)+C5/(F^2*T^2)+C6/(F*T^3)+C7/(F^2*T^3)+C8/T^4+C9/(
F*T^4)-.5 @ GOTO 205
200 P=D1+D2*T+D3*T^2+D4*T^3+D5/F+D6*T/F+D7*T^2/F+D8*T/F^2-.5
205 P=ABS(P)*1.005
210 SUBEND
```

VAR	OCCURS IN LINE	
F	100 ,195 ,195 ,195 195 ,195 ,195 ,195 200 ,200 ,200 ,200	degrees of freedom
T	100 ,190 ,195 ,195 195 ,195 ,195 ,195 200 ,200 ,200 ,200 200 ,200	Student's t statistic
P	100 ,195 ,200 ,205 205	percentage points
C1	145 ,195	
D1	145 ,200	
C2	150 ,195	
D2	150 ,200	
C3	155 ,195	
D3	155 ,200	
C4	160 ,195	
D4	160 ,200	
C5	165 ,195	
D5	165 ,200	
C6	170 ,195	
D6	170 ,200	
C7	175 ,195 ,195 ,195	
D7	175 ,200	
C8	180 ,195	
D8	180 ,200	
C9	185 ,195	

```
100 SUB "LOAD" (C$,A(),R(,),D(,),C(,),B1(),B2(),DO$,TO$)
105 !
110 ! Have user select a test to load and then load it.  AUG 87
115 !
120 OPTION BASE 1@ Q$=".CALDAT" @ DIM L(16),S$[30],T$[960]
125 I=0
130 !
135 ! Allow user to search tests for specific info.
140 !
145 CLEAR @ DISP "Enter a search specific or hit"
150 CALL "QUERY" ( " END LINE for the full table.",R,D,S$ )
155 !
160 ! Load the TOC.
165 !
170 ON ERROR GOTO 315 @ ASSIGN# 1 TO "CONTENTS"&Q$ @ OFF ERROR
175 READ# 1 ; N,L(),T$@ IF N=0 THEN 320
180 !
185 ! Search for a specific, if requested.
190 !
195 ON R GOTO 200,260,335
200 IF I=N THEN P=0 @ GOTO 210
205 I=I*60+1 @ P=POS(T$[I],S$)
210 IF NOT P THEN DISP @ DISP "Specific not found." @ WAIT 2000 @ GOTO 125
215 P=P+I-1 @ I=INT((P+59)/60)
220 CLEAR @ DISP "You are about to LOAD:" @ DISP @ L=I*60-59
225 DISP USING 230 ; T$[L,L+29],T$[L+30,L+39],T$[L+50,L+59],I,T$[L+40,L+49]
230 IMAGE X,30A / X,11A,"Folder # ",10A / X,"@ TEST-",D,3X,"Serial # ",10A
235 DISP @ DISP "Is this correct?" @ CALL "YESNO" ( R )
240 ON R GOTO 280,200,145
245 !
250 ! Allow user to select a test from the full table.
255 !
260 CALL "SELECT" ( I,N,L(),T$ ) @ SCRATCHSUB "SELECT" @ IF NOT I THEN 335
265 !
270 ! Load the chosen test.
275 !
280 CRT OFF @ ASSIGN# 1 TO "TEST-"&VAL$(L(I))&Q$
285 READ# 1 ; A(),R(,),D(,),C(,),B1(),B2(),DO$
290 FOR P=1 TO 6 @ READ# 1 ; Z$@ SLET TO$(P) = Z$ @ NEXT P
295 C$=T$[I*60-59,I*60] @ CLEAR @ CRT ON @ SUBEXIT
300 !
305 ! Display problem messages.
310 !
315 DISP "Can't find data disk." @ GOTO 325
320 DISP "There are no tests on the data  disk."
325 CRT ON @ WAIT 2000
330 !
335 SUBEND
```

VAR	OCCURS IN LINE	
C $	100 ,295	test info from TOC (see main program xref)
A ( )	100 ,285	test info array (see main program xref)
R (,)	100 ,285	range parameters (see main program xref)
D (,)	100 ,285	test meter data. (see main program xref)
C (,)	100 ,285	check meter data. (see main program xref)
B1( )	100 ,285	no. of readings at each point of test meter
B2( )	100 ,285	no. of readings at each point of check meter
DO$	100 ,285	date of test
TO$	100 ,290	test and check meter info (see main program)
Q $	120 ,170 ,280	contains "CALDAT" -- saves some memory
L ()	120 ,175 ,260 ,280	file name numbers. (see STORE xref)
S $	120 ,150 ,205	string for which to search in TOC
T $	120 ,175 ,205 ,225 225 ,225 ,225 ,260 295	table of contents (TOC) file. (see STORE)
I	125 ,200 ,205 ,205 205 ,215 ,215 ,220 225 ,260 ,260 ,280 295 ,295	no. of test in T$ under consideration. also is a loop control
R	150 ,195 ,235 ,240	information about user's reply
D	150	dummy variable
N	175 ,175 ,200 ,260	no. of elements (tests) in TOC
P	200 ,205 ,210 ,215 215 ,215 ,290 ,290 290	position of search specific in T$. also is a loop control
L	220 ,225 ,225 ,225 225 ,225 ,225 ,225 225	position of beginning of test information for the test under consideration
Z $	290 ,290	intermediate string used to transfer meter info

```
100 SUB "MENU" (R,A$,P)
105 !
110 ! This program has the user select an option from among a
115 ! list of options.  JUL 87
120 !
125 DIM L$[10]
130 !
135 ! Show the menu.
140 !
145 ALPHA 1 @ CLEAR @ P=0 @ K0=0
150 FOR I=1 TO R
155 DISP USING "10X,15A" ; GET$(A$(I))
160 NEXT I
165 !
170 ! Act on key.
175 !
180 ON KYBD K0,CHR$(32)&CHR$(143)&CHR$(154)&CHR$(161)&CHR$(162) GOTO 195
185 GOTO 210
190 GOTO 190
195 IF K0=143 OR K0=154 THEN 200 ELSE GOTO 210
200 CLEAR @ IF P=0 THEN 145
205 SUBEXIT
210 IF K0=161 THEN P=(P+R-2) MOD R+1 ELSE P=P MOD R+1
215 OFF CURSOR @ ALPHA P,8 @ AREAD L$ @ ON CURSOR
220 IF L$[4,5]="  " THEN 210
225 GOTO 190 @ SUBEND
```

VAR	OCCURS IN LINE	
R	100 ,150 ,210 ,210 210	no. of options in menu
A $	100 ,155	array of strings of menu options
P	100 ,145 ,200 ,210 210 ,210 ,210 ,215	cursor row and menu option no.
L $	125 ,215 ,220	used to see if cursor isn't on an option
K0	145 ,180 ,195 ,195 210	programmed key that the user presses
I	150 ,155 ,160	menu option no. loop control

```
100 SUB "PDATA" (R(,),D(,),B1(),A,B,R1)
105 !
110 ! This program prints raw data to the internal printer.
115 !
120 OPTION BASE 1
125 PRINT @ PRINT " (I)     Y(I)     YHAT  RESIDUALS"
130 PRINT "DEGREES DEGREES DEGREES MILLIDEG"
135 PRINT
140 FOR I2=R(R1,1) TO R(R1+1,1)-1
145 FOR J2=2 TO B1(I2)+1
150 Y=B*D(I2,1)+A
155 PRINT USING 160 ; D(I2,1),D(I2,J2),Y,(D(I2,J2)-Y-360*(D(I2,J2)>359 AND D(I2,
J2)<361))*1000
160 IMAGE 3DZ.2D,4DZ.3D,4DZ.3D,M3DZ.D
165 NEXT J2 @ NEXT I2
170 PRINT @ PRINT
175 SUBEND
```

VAR	OCCURS IN LINE	
R (,)	100 ,140 ,140	range parameters (see main program xref)
D (,)	100 ,150 ,155 ,155 155 ,155 ,155	test or check meter data (see main program)
B1( )	100 ,145	no. of readings at each point of test meter
A	100 ,150	$\hat{a}$ (fitted y-intercept)
B	100 ,150	$\hat{b}$ (fitted slope)
R1	100 ,140 ,140	range no.
I2	140 ,145 ,150 ,155 155 ,155 ,155 ,155 165	data point no. loop control
J2	145 ,155 ,155 ,155 155 ,165	reading no. loop control
Y	150 ,155 ,155	fitted angle

```
100 SUB "PGHEAD" (TO$) ! JUL 87
105 !
110 ! This program prints the page heading to the Qume printer.
115 !
120 OPTION BASE 1@ T=13 @ CONTROL 10,3 ; 15@ PRINTER IS 10,92
125 CLEAR @ CALL "QUERY" ( "Enter page number.",R,P,Z$ )
130 ON R GOTO 135,125,155
135 FOR I=1 TO 4 @ PRINT @ NEXT I
140 PRINT TAB(T);"Phase Meter";TAB(35+T);"-";P;"-"
145 PRINT TAB(T);GET$(TO$(1));" Model ";GET$(TO$(2))
150 PRINT TAB(T);"Serial No. ";GET$(TO$(3)) @ PRINT
155 SUBEND
```

VAR	OCCURS IN LINE	
TO$	100 ,145 ,145 ,150	test and check meter info (see main program)
T	120 ,140 ,140 ,145	constant tab offset used to save memory
	150	
R	125 ,130	information about user's reply
P	125 ,140	page no.
Z $	125	dummy string
I	135 ,135	loop control

```
100 SUB "PLOT" (C$,D(,),R(,),B(),R1,S1$,N1,TO$,DO$)
105 !
110 ! This program graphs data for visual analysis.  JUL 87
115 !
120 OPTION BASE 1
125 DIM M2$[100]
130 SARRAY M2$
135 !
140 ! Have user select method of graphing.
145 !
150 ALPHA 1 @ CLEAR
155 C=0 @ M=5
160 SLET M2$(1) = "Plot Data"
165 SLET M2$(2) = "Print Plot"
170 SLET M2$(3) = "Overlay"
175 SLET M2$(5) = "Main Menu"
180 CALL "MENU" ( M,M2$,C )
185 ON C GOTO 205,195,220,100,610
190 ! Print plot.
195 SFLAG 3 @ GOTO 210
200 ! Plot data on a new screen.
205 CFLAG 3
210 PEN 1 @ GCLEAR @ CFLAG 2 @ GOTO 240
215 ! Overlay.
220 SFLAG 2
225 !
230 ! Prompt user for parameters for this graph.
235 !
240 CLEAR @ CALL "QUERY" ( "Enter range.",R,R1,Z$ )
245 IF R1<1 OR R1>8 THEN 240
250 ON R GOTO 260,240,155
255 !
260 C=0 @ M=2 @ CFLAG 44
265 SLET M2$(1) = "Avg. Data"
270 SLET M2$(2) = "All Data"
275 CALL "MENU" ( M,M2$,C )
280 ON C GOTO 295,285
285 SFLAG 44
290 !
295 CALL "QUERY" ( "Enter representation symbol.",R,Z,S$ )
300 R1=(R1-1) MOD 10+1
305 IF R(R1,2)=0 THEN 155
310 !
315 CALL "QUERY" ( "Enter scale of correction.",R,C1,Z$ )
320 ON R GOTO 340,315,155
325 !
330 ! Set up the graphics display if this isn't an overlay.
335 !
340 IF FLAG(2) THEN 415
345 SCALE -10,360,-C1,C1
350 XAXIS 0,10 @ YAXIS 0,.2*C1
355 FOR A=30 TO 360 STEP 30
360 MOVE A,.1*C1
365 LDIR 90 @ LABEL VAL$(A)
370 MOVE A,.05*C1 @ IDRAW 0,-(.1*C1)
```

```
375 NEXT A
380 FOR Y=-(.8*C1) TO .8*C1 STEP .2*C1
385 IF Y=0 OR Y=.2*C1 THEN 395
390 MOVE 20,Y-.05*C1 @ LDIR 0 @ LABEL VAL$(Y)
395 NEXT Y
400 !
405 ! Graph average readings.
410 !
415 IF FLAG(44) THEN 460
420 FOR I=R(R1,1) TO R(R1+1,1)-1
425 X=D(I,1)-1.46 @ Y1=-(D(I,8)-D(I,1)+.013*C1)
430 MOVE X,Y1 @ LABEL S$ @ ! PLOT CORRECTION
435 NEXT I
440 GOTO 485
445 !
450 ! Graph every reading.
455 !
460 FOR I=R(R1,1) TO R(R1+1,1)-1
465 FOR J=2 TO B(I)+1
470 X=D(I,1)-1.46 @ Y1=-(D(I,J)-D(I,1)+.013*C1)+360*(D(I,J)>359 AND D(I,J)<361)
475 MOVE X,Y1 @ LABEL S$ @ ! PLOT CORRECTION
480 NEXT J @ NEXT I
485 !
490 ! Wait for user to press <CONT>.
495 !
500 PAUSE
505 !
510 ! Allow user to see display as a line graph of averages.
515 !
520 DISP "Connect the averages?" @ CALL "YESNO" ( R ) @ ON R GOTO 525,575.155
525 Z=0
530 FOR I=R(R1,1) TO R(R1+1,1)-1
535 X=D(I,1) @ Y1=-(D(I,8)-X)
540 IF Z=0 THEN MOVE X,Y1 ELSE DRAW X,Y1
545 Z=Z+1
550 NEXT I
555 PENUP
560 !
565 ! Copy the graph to the printer if appropriate.
570 !
575 IF FLAG(3) THEN 580 ELSE GOTO 595
580 CALL "HEADER" ( C$,S1$,R1,R(,),3,N1,M0,T0$,D0$ )
585 PRINT @ PRINT TAB(13);"CORRECTION" @ PRINT
590 GRAPH @ COPY
595 PAUSE
600 GOTO 155
605 !
610 SUBEND
```

VAR	OCCURS IN LINE	
C $	100 ,580	test info from TOC (see main program xref)
D (,)	100 ,425 ,425 ,425 470 ,470 ,470 ,470 470 ,535 ,535	test or check meter data (see main program xref)
R (,)	100 ,305 ,420 ,420 460 ,460 ,530 ,530 580	array of range parameters (see main program xref)
B ( )	100 ,465	readings/data point of test or check meter
R1	100 ,240 ,245 ,245 300 ,300 ,305 ,420 420 ,460 ,460 ,530 530 ,580	range no.
S1$	100 ,580	present date
N1	100 ,580	N1 is set to point to test meter in printout
TO$	100 ,580	test and check meter info (see main program)
DO$	100 ,580	test date
M2$	125 ,130 ,160 ,165 170 ,175 ,180 ,265 270 ,275	array of strings of menu options
C	155 ,180 ,185 ,260 275 ,280	no. of selected menu option
M	155 ,180 ,260 ,275	no. of options in menu
R	240 ,250 ,295 ,315 320 ,520 ,520	info about user's input
Z $	240 ,315	dummy string
Z	295 ,525 ,540 ,545 545	used as dummy variable and as flag cleared to start and set to continue drawing a line
S $	295 ,430 ,475	contains symbol to represent data
C1	315 ,345 ,345 ,350 360 ,370 ,370 ,380 380 ,380 ,385 ,390 425 ,470	scale of correction
A	355 ,360 ,365 ,370 375 .	phase angle loop control
Y	380 ,385 ,385 ,390 390 ,395	angle offset loop control
I	420 ,425 ,425 ,425 435 ,460 ,465 ,470 470 ,470 ,470 ,470 480 ,530 ,535 ,535 550	data point no. loop control
X	425 ,430 ,470 ,475 535 ,535 ,540 ,540	phase angle x coordinate
Y1	425 ,430 ,470 ,475 535 ,540 ,540	offset y coordinate
J	465 ,470 ,470 ,470 480	reading no. loop control
M0	580	dummy variable

```
100 SUB "QUERY" (Q$,R,N,I$) ! JUL 87
105 OPTION BASE 1@ DIM T$[30]
110 LINPUT Q$,T$ @ IF T$="" THEN R=2 @ SUBEXIT
115 IF T$[1,1]=CHR$(128) THEN R=3 @ SUBEXIT
120 ON ERROR GOTO 125 @ N=VAL(T$)
125 OFF ERROR @ R=1 @ I$=T$ @ SUBEND
```

VAR	OCCURS IN LINE	
Q $	100 ,110	contains question to ask user
R	100 ,110 ,115 ,125	1=expected response; 2=no input; 3=main menu
N	100 ,120	value of user's input
I $	100 ,125	inputted string (changed only if input exists)
T $	105 ,110 ,110 ,115 120 ,125	actual input

```
100 SUB "RANGE" (R(,))
105 !
110 ! This program display the list of ranges.
115 !
120 OPTION BASE 1
125 DISP "RANGE R(,)" @ DISP
130 FOR A=1 TO 8
135 DISP USING 140 ; A,R(A,1),R(A,2),R(A,3),R(A,4)
140 IMAGE 3D,2X,3D,2X,3D.D,2X,3D.D,2X,5D
145 NEXT A
150 DISP @ DISP "PRESS <CONT> TO CONTINUE"
155 PAUSE
160 SUBEND
```

VAR	OCCURS IN LINE	
R (,)	100 ,135 ,135 ,135 135	array of range parameters (see main program xref)
A	130 ,135 ,135 ,135 135 ,135 ,145	range no. loop control

```
100 SUB "REG" (A,B) ! FEB 13-86
105 !
110 ! Print estimated fit for angles at regular intervals.  JUL 87
115 !
120 OPTION BASE 1
125 !
130 ! Prompt user for parameters.
135 !
140 CLEAR @ CALL "QUERY" ( "Enter starting phase angle.",R,S9,Z$ )
145 ON R GOTO 150,100,220
150 CALL "QUERY" ( "Enter ending phase angle.",R,E9,Z$ )
155 ON R GOTO 160,150,220
160 CALL "QUERY" ( "Enter size of increment.",R,I9,Z$ )
165 ON R GOTO 185,160,220
170 !
175 ! Print the angles and their fits.
180 !
185 PRINT @ PRINT "    OBSERVED  CORRECTED"
190 PRINT "     DEGREES   DEGREES" @ PRINT
195 FOR Y=S9 TO E9 STEP I9
200 X=(Y-A)/B
205 PRINT USING "2(2X,M3DZ.3D)" ; Y,X
210 NEXT Y
215 PRINT @ PRINT
220 SUBEND
```

VAR	OCCURS IN LINE	
A	100 ,200	$\hat{a}$ (fitted y-intercept)
B	100 ,200	$\hat{b}$ (fitted slope)
R	140 ,145 ,150 ,155 160 ,165	information about user's reply
S9	140 ,195	starting phase angle
Z $	140 ,150 ,160	dummy string
E9	150 ,195	ending phase angle
I9	160 ,195	angle increment
Y	195 ,200 ,205 ,210	fitted reading
X	200 ,205	meter reading

```
100 ! Calibration Report Program
105 !
110 ! This program displays the main menu and dispatches control
115 ! to the various report printing routines.  AUG 87
120 !
125 OPTION BASE 1@ INTEGER B1(100),B2(100)
130 COM R(10,4),C(100,8),D(100,8),A(5),T0$[100]
135 DIM C$[60],M4$[140],M5$[26],Z(1),N$[20]
140 !
145 ! Display the main menu.
150 !
155 SARRAY M4$,M5$,T0$ @ L=0
160 SLET M4$(1) = "Read File"
165 SLET M4$(3) = "Page Header"
170 SLET M4$(4) = "Introduction"
175 SLET M4$(5) = "Fitted Data"
180 SLET M4$(6) = "Average Data"
185 SLET M4$(7) = "Raw Data"
190 SLET M4$(8) = "Appendix"
195 SLET M4$(9) = "Test Folder"
200 SLET M4$(11) = "Range List"
205 C=0 @ M=11 @ CALL "MENU" ( M,M4$,C )
210 ON C GOTO 230,100,330,350,370,395,420,445,480,100,510
215 !
220 ! Load a test.
225 !
230 CALL "LOAD" ( C$,A(),R(,),D(,),C(,),B1(),B2(),D0$,T0$ ) @ SCRATCHSUB "LOAD"
235 ! N$=folder # without the trailing blanks.
240 FOR I=60 TO 51 STEP -1 @ IF C$[I,I]<>" " THEN 255
245 NEXT I @ I=51
250 ! Get the folder # if it isn't already known.
255 N$=C$[51,I] @ IF N$[1,1]<>" " THEN 290
260 CLEAR @ CALL "QUERY" ( "Enter test folder number.",R,Z,N$ )
265 ON R GOTO 290,260,160
270 ! Get date if it is in wrong format.
275 CLEAR @ DISP "Old date ";D0$;" is in" @ DISP " wrong format."
280 DISP @ CALL "QUERY" ( "Enter date (MM/DD/^^YY).",R,Z,D0$ )
285 OFF ERROR @ ON R GOTO 290,275,160
290 ON ERROR GOTO 275 @ Z=VAL(D0$) @ OFF ERROR
295 C$[31,40]=D0$ @ C$[51,60]=N$
300 ! Save changes.
305 CALL "STORE" ( C$,A(),R(,),D(,),C(,),B1(),B2(),D0$,T0$ )
310 SCRATCHSUB "STORE" @ GOTO 160
315 !
320 ! Print the page header.
325 !
330 GOSUB 530 @ GOTO 160
335 !
340 ! Print the report introduction.
345 !
350 CALL "RPTINTRO" ( D0$,T0$,N$ ) @ SCRATCHSUB "RPTINTRO" @ GOTO 160
355 !
360 ! Print a list of fitted data for angles of regular intervals.
365 !
370 GOSUB 530 @ GOSUB 550 @ GOSUB 560
375 CALL "RPTFIT" ( R(,),S(),R1,A,B,L ) @ SCRATCHSUB "RPTFIT" @ GOTO 480
```

```
380 !
385 ! Print the list of average readings for each test point.
390 !
395 GOSUB 530 @ CALL "RPTAVG" ( R(,),D(,),M(),R5,R1,L )
400 SCRATCHSUB "RPTAVG" @ GOTO 480
405 !
410 ! Print the list of all test meter readings that were taken.
415 !
420 GOSUB 530 @ CALL "RPTRAW" ( R(,),D(,),B1(),R1,L )
425 SCRATCHSUB "RPTRAW" @ GOTO 480
430 !
435 ! Print the statistical info of this calibration (appendix).
440 !
445 GOSUB 530 @ GOSUB 550 @ GOSUB 560
450 CALL "RPTAPP" ( R(,),S(),N,K,A,B,X,Y,S,S1,S2,T1,T2,F1,R1,L )
455 SCRATCHSUB "RPTAPP"
460 !
465 ! Print the folder # at the bottom of the page.
470 !
475 ! L=# of lines printed by last program CALL.
480 IF L>54 THEN 490
485 FOR I=L TO 54 @ PRINT @ NEXT I
490 PRINT @ PRINT TAB(13);"722/";N$;"-";DO$[LEN(DO$)-1] @ GOTO 160
495 !
500 ! Display the list of ranges.
505 !
510 CALL "RANGE" ( R(,) ) @ SCRATCHSUB "RANGE" @ GOTO 160
515 !
520 ! Routine to print the page header.
525 !
530 L=6 @ CALL "PGHEAD" ( TO$ ) @ SCRATCHSUB "PGHEAD" @ RETURN
535 !
540 ! Routine to fit the data and estimate the goodnes of the fit.
545 !
550 CALL "ENTER" ( R(,),D(,),B1(),S(),N,K,A,B,X,Y,S,S1,S2,T1,T2,F1,R1 )
555 SCRATCHSUB "ENTER" @ RETURN
560 CALL "STAT" ( S(),N,K,A,B,X,Y,S,S1,S2,T,T1,T2,F,F1,0 )
565 SCRATCHSUB "STAT" @ RETURN
```

VAR	OCCURS IN LINE	
B1()	125 ,230 ,305 ,420 550	no. of readings at each point of test meter
B2()	125 ,230 ,305	no. of readings at each point of check meter
R (,)	130 ,230 ,305 ,375 395 ,420 ,450 ,510 550	array of range parameters (see main program xref)
C (,)	130 ,230 ,305	check meter data. (see main program xref)
D (,)	130 ,230 ,305 ,395 420 ,550	test meter data. (see main program xref)
A ( )	130 ,230 ,305	test info array (see main program xref)
TO$	130 ,155 ,230 ,305 350 ,530	test and check meter info array (see main program xref)
C $	135 ,230 ,240 ,255 295 ,295 ,305	test info from TOC (see main program xref)
M4$	135 ,155 ,160 ,165 170 ,175 ,180 ,185 190 ,195 ,200 ,205	array of strings of menu options
M5$	135 ,155	unused
Z ()	135	unused
N $	135 ,255 ,255 ,260 295 ,350 ,490	contains folder no.
L	155 ,375 ,395 ,420 450 ,480 ,485 ,530	no. of lines printed on page so far
C	205 ,205 ,210	selected menu option
M	205 ,205	no. of menu options in menu
DO$	230 ,275 ,280 ,290 295 ,305 ,350 ,490 490	test date
I	240 ,240 ,240 ,245 245 ,255 ,485 ,485	loop control
R	260 ,265 ,280 ,285	information about user's reply
Z	260 ,280 ,290	dummy variable
S ()	375 ,450 ,550 ,560	intermediate sums (see ENTER xref)
R1	375 ,395 ,420 ,450 550	range no.
A	375 ,450 ,550 ,560	$\hat{a}$ (fitted y-intercept)
B	375 ,450 ,550 ,560	$\hat{b}$ (fitted slope)
M ()	395	dummy array
R5	395	dummy variable
N	450 ,550 ,560	nk (see ENTER xref)
K	450 ,550 ,560	k (no. of data points in range)
X	450 ,550 ,560	average ideal reading
Y	450 ,550 ,560	average actual reading
S	450 ,550 ,560	standard deviation
S1	450 ,550 ,560	$S(\hat{a})$
S2	450 ,550 ,560	$S(\hat{b})$
T1	450 ,550 ,560	t1
T2	450 ,550 ,560	t2
F1	450 ,550 ,560	F'
T	560	Student's t
F	560	upper 1% point of F distribution

```
100 SUB "RPTAPP" (R(,),S(),N,K,A,B,X,Y,S,S1,S2,T1,T2,F1,R1,L)
105 !
110 ! This program prints the statistical info of the calibration,
115 ! which forms the appendix in the test report.  JUL 87
120 !
125 OPTION BASE 1@ CONTROL 10,3 ; 15@ PRINTER IS 10,92 @ T=13 @ DIM T$[79]
130 !
135 ! Print the title and the first two paragraphs.
140 !
145 PRINT TAB(47);CHR$(27);"IAppendix";CHR$(27);"J" @ PRINT
150 FOR I=1 TO 12 @ READ T$@ PRINT TAB(T);T$ @ NEXT I
155 DATA "     The calibration of this phase meter provides an equation to corre
ct the"
160 DATA "reading obtained from the phase meter so that the result of the measur
ement"
165 DATA "will be close in agreement with the corresponding value supplied by th
e NBS"
170 DATA "standard.  These corrections are calculated from the unprocessed calib
ration"
175 DATA "data obtained during the test, which are shown on separate pages."," "

180 DATA "     Because random fluctuations tend to mask the limiting mean of the
 phase"
185 DATA "meter response at any particular test point, the corrections calculate
d are"
190 DATA "based on predicted values.  These values are obtained by fitting the"
195 DATA "unprocessed data (y) for each set of current, voltage, and frequency"
200 DATA "conditions to an equation which models the average response of the pha
se meter"
205 DATA "to phase angles (x) supplied by the NBS standard."
210 !
215 ! Print the parameters of this range and the statistics.
220 !
225 CALL "RPTRNG" ( R(,),R1 ) @ SCRATCHSUB "RPTRNG"
230 S1$=" " @ S2$="  +" @ IF A<0 THEN S1$="-"
235 IF B<0 THEN S2$="  -"
240 D$="(degrees)" @ PRINT USING 285 ; S1$,ABS(A),S2$,ABS(B),D$ @ PRINT USING 29
0 ; S1,S2,D$
245 CALL "INV_T" ( N-2,T1,A1 ) @ CALL "INV_T" ( N-2,T2,A2 ) @ SCRATCHSUB "INV_T"

250 PRINT USING 295 ; CHR$(27)&"D3"&CHR$(27)&"U",ABS(A1*2),ABS(A2*2) @ PRINT
255 PRINT USING 300 ; S,S*2,D$ @ PRINT USING 305 ; F1 @ CALL "INV_F" ( F1,K-2,N-
K,A2 )
260 SCRATCHSUB "INV_F" @ PRINT USING 310 ; CHR$(27)&"D4"&CHR$(27)&"U",A2 @ PRINT

265 PRINT TAB(T);"Estimated limits of phase offset from NBS standard:" @ PRINT
270 S1$="+" @ IF X<Y THEN S1$="-"
275 PRINT USING 315 ; S(8),D$ @ PRINT USING 320 ; S1$,ABS(X-Y),S(9),D$
280 PRINT USING 325 ; S(10),D$ @ PRINT
285 IMAGE 12X,"Predicted value",9X,"y' = ",A,DZ.6D,3A,2DZ.6D," x",12X,9A
290 IMAGE 12X,"Standard errors",15X,"(",Z.6D,")   (",Z.6D,")",13X,9A
295 IMAGE 12X,"Significance levels",5A,10X,"(",Z.3D,")",6X,"(",Z.3D,")"
300 IMAGE 12X,"Residual standard deviation",8X,"s =",DZ.6D,"   2s =",DZ.5D,4X,9A
```

```
305 IMAGE 12X,"Lack-of-fit",24X,"F'=",DZ.3D
310 IMAGE 12X,"Significance level",5A,19X,"(",Z.3D,")"
315 IMAGE 17X,"without corrections",8X,"(x' = y)",12X,3DZ.3D,6X,9A
320 IMAGE 17X,"with a constant correction (x' = y ",A,DZ.3D,")",4X,3DZ.3D,6X,9A
325 IMAGE 17X,"using the fitted linear equation (see above)   ",3DZ.3D,6X,9A
330 !
335 ! Print the footnotes.
340 !
345 PRINT TAB(7);CHR$(27);"I";TAB(36);CHR$(27);"J" @ PRINT
350 PRINT CHR$(27);"C12";CHR$(27);"D3";CHR$(27);"U";
355 FOR I=1 TO 6 @ READ T$@ PRINT CHR$(27);"C17";T$ @ NEXT I
360 DATA "Significance levels are derived using the statistical t-tests to decid
e"
365 DATA "if the intercept and slope of the fitted straight line are different f
rom"
370 DATA "their ideal values, zero and one respectively.  A level near zero (les
s"
375 DATA "than or equal to 0.05) shows that the associated parameter is probably
"
380 DATA "different from the ideal value."," "
385 PRINT CHR$(27);"C12";CHR$(27);"D4";CHR$(27);"U";
390 FOR I=1 TO 8 @ READ T$@ PRINT CHR$(27);"C17";T$ @ NEXT I
395 DATA "The significance level of F' is associated with an objective statistic
al"
400 DATA "test for the adequacy of a linear model relating the user's phase mete
r"
405 DATA "response and the NBS assigned values.  Significance levels near zero (
less"
410 DATA "than or equal to 0.01) indicate that the assumption of a straight line
 as a"
415 DATA "model for the phase meter response may be incorrect.  However, if the"

420 DATA "variability of the repeat readings is of the same order as the resolut
ion"
425 DATA "of the meter, and the data points are therefore not normally distribut
ed,"
430 DATA "the table of values on which this test is based are not applicable."
435 !
440 L=55 @ SUBEND
```

VAR	OCCURS IN LINE	
R (,)	100 ,225	range parameters (see main program xref)
S ( )	100 ,275 ,275 ,280	intermediate sums (see ENTER xref)
N	100 ,245 ,245 ,255	nk (see ENTER xref)
K	100 ,255 ,255	k (no. of data points in range)
A	100 ,230 ,240	$\hat{a}$ (fitted y-intercept)
B	100 ,235 ,240	$\hat{b}$ (fitted slope)
X	100 ,270 ,275	average ideal reading
Y	100 ,270 ,275	average actual reading
S	100 ,255 ,255	standard deviation
S1	100 ,240	$S(\hat{a})$
S2	100 ,240	$S(\hat{b})$
T1	100 ,245	t1
T2	100 ,245	t2
F1	100 ,255 ,255	F'
R1	100 ,225	range no.
L	100 ,440	no. of lines printed by this program
T	125 ,150 ,265 ,345	constant tab offset used to save memory
T $	125 ,150 ,150 ,355 355 ,390 ,390	text read from data statements
I	150 ,150 ,355 ,355 390 ,390	loop control
S1$	230 ,230 ,240 ,270 270 ,275	contains sign of $\hat{a}$ on lines 230-240 and sign of uncorrected offset
S2$	230 ,235 ,240	contains sign of $\hat{b}$
D $	240 ,240 ,240 ,255 275 ,275 ,280	contains "(degrees)" -- saves memory
A1	245 ,250	% points for statistic t1
A2	245 ,250 ,255 ,260	% points for statistic t2

```
100 SUB "RPTAVG" (R(,),D(,),M(),R5,R1,L) ! July 1987
105 !
110 ! This program prints the average readings for each test
115 ! point.  JUL 87
120 !
125 OPTION BASE 1
130 !
135 ! This function rounds X to the thousandths place.
140 !
145 DEF FNP(X) = SGN(X)*ABS(INT(X*1000+.5)/1000)
150 !
155 ! Prompt user for range.
160 !
165 CLEAR @ CALL "QUERY" ( "Enter range.",R,R1,Z$ )
170 ON R GOTO 175,165,280
175 IF R(R1,2)=0 THEN DISP "Data not present for range ";R1 ELSE GOTO 200
180 DISP @ DISP "Press <CONT> to continue." @ PAUSE @ GOTO 280
185 !
190 ! Print the range parameters and the table column labels.
195 !
200 PRINT @ PRINT @ CALL "RPTRNG" ( R(,),R1 ) @ SCRATCHSUB "RPTRNG" @ PRINT
205 PRINT TAB(13);"Phase Angle of NBS";TAB(42);"Average Reading";TAB(69);"Correc
tion"
210 PRINT TAB(18);"Standard";TAB(42);"of Phase Meter*    [Add to Phase Meter Rea
dings]"
215 PRINT TAB(18);"(Degrees)";TAB(45);"(Degrees)";TAB(70);"(Degrees)"
220 !
225 ! Print the list of average readings.
230 !
235 PRINT @ N=21 @ FOR X=R(R1,1) TO R(R1+1,1)-1
240 PRINT USING 245 ; D(X,1),D(X,8),FNP(D(X,1))-FNP(D(X,8))
245 IMAGE 12X,6X,2DZ.3D,20X,2DZ.3D,17X,2DZ.3D
250 N=N+1 @ NEXT X
255 !
260 ! Print the footnote.
265 !
270 FOR I=N TO 54 @ PRINT @ NEXT I
275 PRINT TAB(13);"* Average of four readings." @ L=52
280 SUBEND
```

VAR	OCCURS IN LINE	
R (,)	100 ,175 ,200 ,235 235	array of range parameters (see main program xref)
D (,)	100 ,240 ,240 ,240 240	any meter data. (see main program xref)
M ( )	100	unused
R5	100	unused
R1	100 ,165 ,175 ,175 200 ,235 ,235	range no.
L	100 ,275	no. of lines printed by this program
R	165 ,170	information about user's reply
Z $	165	dummy string
N	235 ,250 ,250 ,270	no. of lines printed by end of table
X	235 ,240 ,240 ,240 240 ,250	data point no. loop control
I	270 ,270	loop control

```
100 SUB "RPTFIT" (R(,),S(),R1,A,B,L)
105 !
110 ! This program prints a list of fitted angles for angles
115 ! read on the meter.  JUL 87
120 !
125 OPTION BASE 1
130 !
135 ! Query user for necessity of fit.
140 !
145 CLEAR @ DISP "Limits to Offset:" @ DISP @ DISP USING 150 ; S(8),S(9),S(10) @
 DISP
150 IMAGE "  no correction",8DZ.3D/ "  constant correction",2DZ.3D/ "  full corr
ection",6DZ.3D
155 DISP "Is correction needed?" @ CALL "YESNO" ( R ) @ ON R GOTO 175,445,455
160 !
165 ! Prompt user for info about this list.
170 !
175 CALL "QUERY" ( "Enter starting phase angle.",R,A1,Z$ )
180 ON R GOTO 190,175,455
185 !
190 CALL "QUERY" ( "Enter ending phase angle.",R,A2,Z$ )
195 ON R GOTO 205,190,455
200 !
205 CALL "QUERY" ( "Enter angle increment.",R,I1,Z$ )
210 ON R GOTO 220,205,455
215 !
220 CALL "QUERY" ( "Enter decimals of accuracy.",R,D,Z$ )
225 ON R GOTO 230,220,455
230 IF D<1 OR D>3 THEN 220
235 !
240 ! Print the fit equation, the range, and the table header.
245 !
250 S1$=" " @ S2$=" +" @ IF -(A/B)<0 THEN S1$="-"
255 IF B<0 THEN S2$=" -"
260 GOSUB 475 @ PRINT USING 265 ; S1$,ABS(A/B),S2$,ABS(1/B) @ PRINT @ PRINT @ PR
INT
265 IMAGE 12X,"Corrected Phase Angle:*   x'= ",A,DZ.6D,2A,DZ.6D," y"
270 PRINT TAB(28);"Table of Corrected Phase Angles (x') in Degrees";CHR$(27);"D*
";CHR$(27);"U"
275 FOR I=1 TO 4 @ PRINT @ NEXT I @ PRINT USING 280
280 IMAGE 21X,"OBSERVED",7X,"CORRECTED",12X,"OBSERVED",7X,"CORRECTED"
285 T$="PHASE ANGLE" @ PRINT TAB(21);T$;TAB(36);T$;TAB(57);T$;TAB(72);T$
290 T$="(Degrees)" @ PRINT TAB(22);T$;TAB(37);T$;TAB(58);T$;TAB(73);T$ @ PRINT @
 PRINT
295 !
300 ! Print the table.  D1=span of degrees for half of table,
305 ! used to print table in two columns.
310 !
315 L=31 @ D1=INT((A2-A1)/I1/2+1)*I1 @ FOR I=A1 TO A1+D1-I1 STEP I1
320 L=L+1 @ Y1=1/B*I-A/B @ IF I+D1>A2 THEN 365
325 Y2=1/B*(I+D1)-A/B
330 ON D GOTO 335,345,355
335 PRINT USING 340 ; I,Y1,I+D1,Y2 @ GOTO 400
340 IMAGE 25DZ.D,11DZ.2D,18DZ.D,11DZ.2D
345 PRINT USING 350 ; I,Y1,I+D1,Y2 @ GOTO 400
350 IMAGE 24DZ.2D,11DZ.3D,16DZ.2D,11DZ.3D
```

```
355 PRINT USING 360 ; I,Y1,I+D1,Y2 @ GOTO 400
360 IMAGE 24DZ.3D,10DZ.3D,16DZ.3D,10DZ.3D
365 ON D GOTO 370,380,390
370 PRINT USING 375 ; I,Y1 @ GOTO 400
375 IMAGE 25DZ.D,11DZ.2D
380 PRINT USING 385 ; I,Y1 @ GOTO 400
385 IMAGE 24DZ.2D,11DZ.3D
390 PRINT USING 395 ; I,Y1 @ GOTO 400
395 IMAGE 24DZ.3D,10DZ.3D
400 NEXT I
405 !
410 ! Print the footnote.
415 !
420 PRINT @ PRINT @ PRINT TAB(24);"* Calculated values based on linear model (se
e appendix)"
425 GOTO 455
430 !
435 ! Print notice that fit is unnecessary.
440 !
445 GOSUB 475 @ PRINT TAB(13);"No correction is needed to bring the observed pha
se angle";
450 PRINT " reading into" @ PRINT TAB(13);"agreement with the NBS standard." @ L
=16
455 SUBEND
460 !
465 ! Routine to print range parameters.
470 !
475 PRINT @ PRINT @ CALL "RPTRNG" ( R(,),R1 ) @ SCRATCHSUB "RPTRNG"
480 PRINT @ RETURN
```

VAR	OCCURS IN LINE	
R (,)	100 ,475	range parameters (see main program xref)
S ( )	100 ,145 ,145 ,145	intermediate sums (see ENTER xref)
R1	100 ,475	range no.
A	100 ,250 ,260 ,320 325	$\hat{a}$ (fitted y-intercept)
B	100 ,250 ,255 ,260 260 ,320 ,320 ,325 325	$\hat{b}$ (fitted slope)
L	100 ,315 ,320 ,320 450	no. of lines printed by this program
R	155 ,155 ,175 ,180 190 ,195 ,205 ,210 220 ,225	information about user's reply
A1	175 ,315 ,315 ,315	starting phase angle
Z $	175 ,190 ,205 ,220	dummy string
A2	190 ,315 ,320	ending phase angle
I1	205 ,315 ,315 ,315 315	angle increment
D	220 ,230 ,230 ,330 365	decimals of accuracy
S1$	250 ,250 ,260	contains sign of y-intercept
S2$	250 ,255 ,260	contains sign of slope
I	275 ,275 ,315 ,320 320 ,325 ,335 ,335 345 ,345 ,355 ,355 370 ,380 ,390 ,400	multi-purpose loop control
T $	285 ,285 ,285 ,285 285 ,290 ,290 ,290 290 ,290	constant text -- used to save memory
D1	315 ,315 ,320 ,325 335 ,345 ,355	span of degrees for half of the table
Y1	320 ,335 ,345 ,355 370 ,380 ,390	left column corrected angle
Y2	325 ,335 ,345 ,355	right column corrected angle

```
100 SUB "RPTRAW" (R(,),D(,),B1(),R1,L)
105 !
110 ! This program prints a table of all the readings in a
115 ! given range. JUL 87
120 !
125 OPTION BASE 1
130 !
135 ! Prompt user for info about this table.
140 !
145 CLEAR @ CALL "QUERY" ( "Enter range.",R,R1,Z$ )
150 ON R GOTO 160,145,390
155 !
160 CALL "QUERY" ( "Enter decimals of accuracy.",R,D,Z$ )
165 ON R GOTO 170,160,390
170 IF D<1 OR D>3 THEN 160
175 !
180 ! Print title, range parameters, and table header.
185 !
190 PRINT @ PRINT @ PRINT TAB(13);"Unprocessed Calibration Data for Range:"
195 CALL "RPTRNG" ( R(,),R1 ) @ PRINT @ PRINT @ PRINT
200 PRINT TAB(19);"NBS STANDARD   METER UNDER TEST      NBS STANDARD   METER UND
ER TEST"
205 T$="(degrees)" @ PRINT TAB(20);T$;TAB(37);T$;TAB(57);T$;TAB(74);T$ @ PRINT
210 !
215 ! Initialize the pointers needed to print the table.
220 !
225 ! N=total # of readings.
230 N=0 @ FOR I=1 TO R(R1+1,1)-1 @ N=N+B1(I) @ NEXT I
235 ! K1,K2=present left, right column test point #; J1,J2=
240 ! present reading in test point of left, right column;
245 ! L=# of rows in table.
250 ! Point K1,K2,J1,J2 to beginning of the requested range.
255 K1=1 @ K2=1 @ J1=0 @ J2=0 @ L=INT(N/2+.5) @ FOR I=1 TO L
260 J2=J2+1 @ IF J2>B1(K2) THEN K2=K2+1 @ J2=1
265 NEXT I
270 !
275 ! Print the table.
280 !
285 FOR I=1 TO L
290 J1=J1+1 @ IF J1>B1(K1) THEN K1=K1+1 @ J1=1
295 J2=J2+1 @ IF J2>B1(K2) THEN K2=K2+1 @ J2=1
300 IF I=L AND N/2<>INT(N/2) THEN 340
305 ON D GOTO 310,320,330
310 PRINT USING 315 ; D(K1,1),D(K1,J1),D(K2,1),D(K2,J2) @ GOTO 375
315 IMAGE 22DZ.3D,13DZ.D,16DZ.3D,13DZ.D
320 PRINT USING 325 ; D(K1,1),D(K1,J1),D(K2,1),D(K2,J2) @ GOTO 375
325 IMAGE 22DZ.3D,12DZ.2D,16DZ.3D,12DZ.2D
330 PRINT USING 335 ; D(K1,1),D(K1,J1),D(K2,1),D(K2,J2) @ GOTO 375
335 IMAGE 22DZ.3D,12DZ.3D,15DZ.3D,12DZ.3D
340 ON D GOTO 345,355,365
345 PRINT USING 350 ; D(K1,1),D(K1,J1) @ GOTO 375
350 IMAGE 22DZ.3D,13DZ.D
```

```
355 PRINT USING 360 ; D(K1,1),D(K1,J1) @ GOTO 375
360 IMAGE 22DZ.3D,12DZ.2D
365 PRINT USING 370 ; D(K1,1),D(K1,J1) @ GOTO 375
370 IMAGE 22DZ.3D,12DZ.3D
375 NEXT I
380 !
385 L=L+19
390 SUBEND
```

VAR	OCCURS IN LINE	
R (,)	100 ,195 ,230	range parameters (see main program xref)
D (,)	100 ,310 ,310 ,310 310 ,320 ,320 ,320 320 ,330 ,330 ,330 330 ,345 ,345 ,355 355 ,365 ,365	test or check meter data. (see main program xref)
B1( )	100 ,230 ,260 ,290 295	no. of readings at each point of test or check meter
R1	100 ,145 ,195 ,230	range no.
L	100 ,255 ,255 ,285 300 ,385 ,385	no. of lines printed by this program
R	145 ,150 ,160 ,165	information about user's reply
Z $	145 ,160	dummy string
D	160 ,170 ,170 ,305 340	decimals of accuracy
T $	205 ,205 ,205 ,205 205	constant text used to save memory
N	230 ,230 ,230 ,255 300 ,300	total no. of readings
I	230 ,230 ,230 ,255 265 ,285 ,300 ,375	loop control
K1	255 ,290 ,290 ,290 310 ,310 ,320 ,320 330 ,330 ,345 ,345 355 ,355 ,365 ,365	left column test point no.
K2	255 ,260 ,260 ,260 295 ,295 ,295 ,310 310 ,320 ,320 ,330 330	right column test point no.
J1	255 ,290 ,290 ,290 290 ,310 ,320 ,330 345 ,355 ,365	left column reading no.
J2	255 ,260 ,260 ,260 260 ,295 ,295 ,295 295 ,310 ,320 ,330	right column reading no.

```
100 SUB "RPTRNG" (R(,),R1)
105 OPTION BASE 1
110 T1$=" Voltage: " @ T2$=" Current: " @ T3$=T1$
115 U1$=" V" @ U2$=" A" @ U3$=U1$
120 IF R(R1,2)<0 THEN T1$=T2$ @ U1$=U2$
125 IF R(R1,3)>0 THEN T2$=T3$ @ U2$=U3$
130 T3$="Frequency:" @ U3$=" Hz" @ F=R(R1,4) @ IF F>=1000 THEN F=F/1000 @ U3$="
kHz"
135 F1=F @ I=1
140 IF F1<>INT(F1) THEN I=I+1 @ F1=F1*10 @ GOTO 140
145 PRINT @ PRINT USING 150 ; T1$,ABS(R(R1,2)),U1$ @ PRINT USING 155 ; T2$,ABS(R
(R1,3)),U2$
150 IMAGE 12X,"Reference Signal",10A,12DZ.2D,2A
155 IMAGE 12X,"Variable Phase Signal",10A,7DZ.2D,2A
160 ON I GOTO 165,175,185,195
165 PRINT USING 170 ; T3$,F,U3$ @ GOTO 205
170 IMAGE 12X,10A,29X,3D,4A
175 PRINT USING 180 ; T3$,F,U3$ @ GOTO 205
180 IMAGE 12X,10A,26X,3DZ.D,4A
185 PRINT USING 190 ; T3$,F,U3$ @ GOTO 205
190 IMAGE 12X,10A,25X,3DZ.2D,4A
195 PRINT USING 200 ; T3$,F,U3$
200 IMAGE 12X,10A,24X,3DZ.3D,4A
205 PRINT @ SUBEND
```

VAR	OCCURS IN LINE	
R (,)	100 ,120 ,125 ,130 145 ,145	array of range parameters (see main program xref)
R1	100 ,120 ,125 ,130 145 ,145	range no.
T1$	110 ,110 ,120 ,145	reference signal units
T2$	110 ,120 ,125 ,145	variable signal units
T3$	110 ,125 ,130 ,145 145 ,165 ,165 ,175 175 ,185 ,185 ,195 195	multi-purpose string. on lines 110-125 it contains " Voltage: ". from line 130 it contains "Frequency:"
U1$	115 ,115 ,120 ,145	abbreviated reference signal units
U2$	115 ,120 ,125 ,145	abbreviated variable signal units
U3$	115 ,125 ,130 ,130 165 ,175 ,185 ,195	abbreviated units for units of T3$
F	130 ,130 ,130 ,130 135 ,165 ,175 ,185 195	frequency
F1	135 ,140 ,140 ,140 140	used to determine digits in frequency after the decimal
I	135 ,140 ,140 ,160	no. of digits after decimal +1

```
100 SUB "SEL" (A,B)
105 !
110 ! This program prints the fitted angles for selected test
115 ! meter angles.  JUL 87
120 !
125 OPTION BASE 1
130 !
135 ! Print the table header.
140 !
145 PRINT @ PRINT "    OBSERVED  CORRECTED"
150 PRINT "     DEGREES   DEGREES" @ PRINT
155 !
160 ! Loop to get angle from user and find its fitted value.
165 !
170 CLEAR @ DISP "ENTER PHASE ANGLE"
175 DISP @ DISP @ DISP "Press <k1> to quit."
180 CALL "QUERY" ( "",R,Y,Z$ )
185 ON R GOTO 190,170,205
190 X=(Y-A)/B
195 PRINT USING "2(2X,M3DZ.3D)" ; Y,X
200 GOTO 170
205 PRINT @ PRINT
210 SUBEND
```

VAR	OCCURS IN LINE	
A	100 ,190	$\hat{a}$ (fitted y-intercept)
B	100 ,190	$\hat{b}$ (fitted slope)
R	180 ,185	information about user's reply
Y	180 ,190 ,195	observed degrees
Z $	180	dummy string
X	190 ,195	corrected degrees

```
100 SUB "SELECT" (I,N,L(),T$)
105 !
110 ! This program has the user select a test from the TOC.
115 ! AUG 87
120 !
125 OPTION BASE 1
130 !
135 ! Clear all 4 screens.
140 !
145 FOR I=1 TO 49 STEP 16 @ OFF CURSOR @ ALPHA I @ CLEAR @ NEXT I @ ALPHA 1 @ CR
T OFF
150 !
155 ! Show table of contents (TOC).
160 !
165 FOR P=1 TO N*60-59 STEP 60
170 DISP USING 175 ; T$[P,P+29],T$[P+30,P+39],T$[P+50,P+59],VAL$(L(INT(P/60)+1))
,T$[P+40,P+49]
175 IMAGE X,30A / X,11A,"Folder # ",10A / " @ TEST-",4A,"Serial # ",10A //
180 NEXT P
185 !
190 ! Wait for user to press a key.
195 !
200 I=1 @ K$=CHR$(128)&CHR$(154)&CHR$(161)&CHR$(162)&CHR$(32)
205 OFF CURSOR @ ALPHA I*4-3
210 ON CURSOR @ CRT ON @ ON KYBD K,K$ GOTO 220
215 GOTO 215
220 ON POS(K$,CHR$(K)) GOTO 310,330,240,270,270
225 !
230 ! <Cursor up> moves cursor to previous test.
235 !
240 I=I-1
245 IF I<1 THEN I=N @ GOTO 285
250 IF FP(I/4) THEN 205 ELSE 285
255 !
260 ! <Cursor down> and <Space bar> move cursor to next test.
265 !
270 I=I+1
275 IF I>N THEN I=1
280 IF FP((I-1)/4) THEN 205
285 Q=INT((I-1)/4)*16 @ OFF CURSOR @ CRT OFF @ ALPHA ABS(49-Q) @ ALPHA Q+1 @ GOT
O 205
290 GOTO 205
295 !
300 ! <k1> aborts selection.
305 !
310 I=0
315 !
320 ! END LINE selects a test.
325 !
330 SUBEND
```

VAR	OCCURS IN LINE	
I	100 ,145 ,145 ,145 200 ,205 ,240 ,240 245 ,245 ,250 ,270 270 ,275 ,275 ,280 285 ,310	multi-purpose variable. used as a loop control and as the no. of the element of T$ to which the cursor points
N	100 ,165 ,245 ,275	no. of elements (tests) in TOC
L ( )	100 ,170	file name numbers. (see STORE xref)
T $	100 ,170 ,170 ,170 170	table of contents (TOC) file. contains an array of elements in format of C$
P	165 ,170 ,170 ,170 170 ,170 ,170 ,170 170 ,170 ,180	points to beginning of a test in TOC T$
K $	200 ,210 ,220	string of programmed keys
K	210 ,220	programmed key that the user presses
Q	285 ,285 ,285	no. of logical lines before top of screen

```
100 SUB "STAT" (S(),N,K,A,B,X,Y,S,S1,S2,T,T1,T2,F,F1,O)
105 !
110 ! "STAT" determines the applicability of the linear model,
115 ! determines the significance of differences between fitted
120 ! and standard intercepts and slopes, determines the limit
125 ! to the offset for each level of correction, and prints the
130 ! values of various variables used in the calculations if
135 ! requested.  last modified 7-07-87, 11:28.
140 !
145 ! INPUT: S()=intermediate sums, N=nk, K=k, A=a-hat, B=b-hat,
150 ! X=av. ideal reading, Y=av. actual reading, S=s, S1=S(a-hat),
155 ! S2=S(b-hat), T1=t1, T2=t2, F1=F', O=printout flag (1 is print);
160 ! OUTPUT: T=Student's t, F=upper 1% point of F distribution
165 !
170 OPTION BASE 1
175 SCRATCHSUB "ENTER"
180 DIM X(4),A$[2]
185 X(1),X(2)=0 @ X(3),X(4)=360
190 Q,I=1
195 !
200 ! determine applicability of linear model
205 !
210 CALL "F_TABL" ( .01,K-2,N-K,F ) @ IF NOT O THEN 240
215 PRINT "Linear model is ";@ IF F1>=F THEN PRINT "not ";
220 PRINT "applicable." @ PRINT
225 !
230 ! calculate Student's T
235 !
240 DEF FNZ(A1) = 4.932*((1-A1)^.14-A1^.14)
245 A1=.025 @ N1=N-2 ! ,nk-2
250 T=SQR(N1*EXP(FNZ(A1)^2*(N1-1.5)/(N1-1)^2)-N1)*.991+.00006*N1 @ IF NOT O THEN
 310
255 !
260 ! determine significance of differences between fitted and
265 ! standard intercepts and slopes
270 !
275 PRINT "Intercept is";@ IF T1<=T THEN PRINT " not";
280 GOSUB 590 @ PRINT "zero." @ PRINT
285 PRINT "Slope is";@ IF T2<=T THEN PRINT " not";
290 GOSUB 590 @ PRINT "one." @ PRINT
295 !
300 ! function to calculate R(xt)
305 !
310 DEF FNR
315 IF Q=1 THEN X1=X ELSE X1=Y
320 FNR=S*SQR(2*F2*(1/N+(X(I)-X1)^2/S(5)))
325 FN END
330 !
335 ! function to calculate maximum L(xt) and U(xt)
340 !
345 DEF FNL(A2)
350 L9=0
355 FOR I=1 TO 4
360 L=A+A2+(B-1)*X(I)+(-1)^I*FNR
365 L9=MAX(L9,ABS(L)) @ NEXT I
370 FNL=L9
375 FN END
```

```
380 !
385 ! calculate limit to offset at each level
390 !
395 CALL "F_TABL" ( .05,2,N-2,F2 ) @ SCRATCHSUB "F_TABL"
400 ! no correction
405 L1=FNL(0)
410 ! constant correction
415 L2=FNL(X-Y)
420 ! full correction
425 Q,L3=0
430 FOR I=1 TO 4
435 L=FNR/B @ L3=MAX(L3,ABS(L))
440 NEXT I
445 !
450 S(8)=L1 @ S(9)=L2 @ S(10)=L3 @ IF NOT 0 THEN SUBEND
455 !
460 ! function to round to 1000ths place accuracy
465 !
470 DEF FND(X) = SGN(X)*INT(ABS(X*1000)+.5)/1000
475 !
480 ! print values of various variables
485 !
490 IF B<0 THEN A$="-" ELSE A$="+" @ ! A$=sign of slope
495 PRINT USING 500 ; A,A$,ABS(B)
500 IMAGE "Predicted"/"y=",MZ.6D,2X,A,2X,Z.6D," x"/
505 PRINT USING 510 ; N,N/K,K,X,Y,T
510 IMAGE "N=",3D/"n=",3D.3D/"k=",3D/"X=",4D.3D/"Y=",4D.3D/"t[.025,nk-2]=",2D.4D
//
515 CALL "INV_T" ( N-2,T1,A1 ) @ A$="a="
520 PRINT USING 525 ; A$,A,A$,S1,A$,T1,A$,ABS(2*A1)
525 IMAGE 2A,MDZ.6D/"s",2A,DZ.6D/"t",2A,DZ.3D/"",2A,DZ.3D//
530 CALL "INV_T" ( N-2,T2,A2 ) @ A$="b="
535 PRINT USING 525 ; A$,B,A$,S2,A$,T2,A$,ABS(2*A2)
540 PRINT USING 545 ; S,F1,SQR(S(7)-S(6)),SQR(S(6)),F
545 IMAGE "s=",MDZ.6D/"F1=",MDZ.3D/"[SL]=",MDZ.3D/ "[SE]=",MDZ.3D/ "F[.01(k-2,k(
n-1))]=",MDZ.3D
550 CALL "INV_F" ( F1,K-2,N-K,A2 ) @ PRINT USING 555 ; A2 @ SCRATCHSUB "INV_F"
555 IMAGE "Level of significance",MZ.3D
560 PRINT USING 565 ; "L1=",L1,"L2=",L2,"L3=",L3
565 IMAGE 3(3A,MZ.3D/)
570 SUBEND
575 !
580 ! this subroutine saves memory, and this line makes up for it
585 !
590 PRINT " significantly" @ PRINT " different from ";@ RETURN
```

VAR	OCCURS IN LINE	
S ( )	100 ,320 ,450 ,450 450 ,540 ,540 ,540	intermediate sums (see ENTER xref)
N	100 ,210 ,245 ,320 395 ,505 ,505 ,515 530 ,550	nk (see ENTER xref)
K	100 ,210 ,210 ,505 505 ,550 ,550	k (no. of test points in range)
A	100 ,360 ,495 ,520	$\hat{a}$ (fitted y-intercept)
B	100 ,360 ,435 ,490 495 ,535	$\hat{b}$ (fitted slope)
X	100 ,315 ,415 ,505	ideal readings, average of
Y	100 ,315 ,415 ,505	average of actual readings
S	100 ,320 ,540	standard deviation
S1	100 ,520	$S(\hat{a})$
S2	100 ,535	$S(\hat{b})$
T	100 ,250 ,275 ,285 505	Students t statistic
T1	100 ,275 ,515 ,520	t1
T2	100 ,285 ,530 ,535	t2
F	100 ,210 ,215 ,540	F statistic that determines model applicability
F1	100 ,215 ,540 ,550	F'
O	100 ,210 ,250 ,450	set to print results to internal printer
X ()	180 ,185 ,185 ,185 185 ,320 ,360	array of lower and upper limit degrees
A $	180 ,490 ,490 ,495 515 ,520 ,520 ,520 520 ,530 ,535 ,535 535 ,535	multi-purpose string.
Q	190 ,315 ,425	set when finding R(xt) for avg. ideal reading
I	190 ,320 ,355 ,360 360 ,365 ,430 ,440	index into X() and loop control
A1	245 ,250 ,515 ,520	percentage points for t1
N1	245 ,250 ,250 ,250 250 ,250	degrees of freedom nk-2
X1	315 ,315 ,320	average of ideal or actual reading
F2	320 ,395	F statistic for limit to offsets
L9	350 ,365 ,365 ,370	greatest offset
L	360 ,365 ,435 ,435	offset for limit X(I)
L1	405 ,450 ,560	offset for no correction
L2	415 ,450 ,560	offset for constant correction
L3	425 ,435 ,435 ,450 560	offset for full correction
A2	530 ,535 ,550 ,550	percentage points for t2

```
100 SUB "STORE" (C$,A(),R(,),D(,),C(,),B1(),B2(),DO$,TO$)
105 !
110 ! This program saves data and updates the table of contents (TOC).  AUG 87
115 !
120 OPTION BASE 1@ DIM L(16),T$[960]
125 C$[31,40]=DO$ @ C$[41,50]=GET$(TO$(3)) @ Q1$=".CALDAT" @ Q2$="CONTENTS"&Q1$
130 !
135 ! Verify that info should be saved.
140 !
145 CLEAR @ DISP "You are about to SAVE data for" @ DISP
150 DISP USING 155 ; C$[1,30],DO$,C$[51],C$[41,50] @ DISP
155 IMAGE X,30A / X,11A,"Folder # ",10A / X,"@ ?",8X,"Serial # ",10A
160 DISP "Is this correct?" @ CALL "YESNO" ( R ) @ ON R GOTO 180,460,460
165 !
170 ! Retrieve TOC.  If there is no TOC then make one.
175 !
180 ON ERROR GOTO 315 @ ASSIGN# 1 TO Q2$ @ OFF ERROR @ READ# 1 ; N,L(),T$
185 !
190 ! Overwrite test if it already exists.
195 !
200 P=POS(T$,C$[1,50]) @ I=INT(P/60)+1 @ IF NOT P THEN 230
205 CLEAR @ DISP "This test is already on disk.   Do you want to overwrite it?"
210 CALL "YESNO" ( R ) @ ON R GOTO 430,460,460
215 !
220 ! Allow user to overwrite an existing test.
225 !
230 CLEAR @ DISP "Do you want to overwrite an      existing test?"
235 CALL "YESNO" ( R ) @ ON R GOTO 240,295,460
240 CLEAR @ DISP "You are about to select the test you want to overwrite..."
245 DISP @ OFF CURSOR
250 WAIT 2000 @ CALL "SELECT" ( I,N,L(),T$ ) @ IF NOT I THEN 230
255 P=I*60-59 @ CLEAR @ DISP "You are about to OVERWRITE" @ DISP
260 DISP USING 265 ; T$[P,P+29],T$[P+30,P+39],T$[P+50,P+59],I,T$[P+40,P+49]
265 IMAGE X,30A / X,11A,"Folder # ",10A / X,"@ TEST-",D,3X,"Serial # ",10A
270 DISP @ DISP "Is this correct?" @ CALL "YESNO" ( R )
275 ON R GOTO 430,230,460
280 !
285 ! See if there is room in TOC for new test.
290 !
295 IF N<16 THEN 375 ELSE CLEAR @ DISP "The data disk is full." @ GOTO 320
300 !
305 ! Initialize disk and TOC with user's permission.
310 !
315 OFF ERROR @ CLEAR @ DISP "You don't have an initialized   data disk in eithe
r drive."
320 DISP @ DISP "Do you want to initialize the   disk in drive 1 (right drive)?"

325 CALL "YESNO" ( R ) @ ON R GOTO 330,460,460
330 DISP @ DISP "All information now on the disk in drive 1 will be lost.  Are
 you sure?"
335 CALL "YESNO" ( R ) @ ON R GOTO 340,460,460
340 CLEAR @ DISP "Initializing.  Please wait."
345 INITIALIZE Q1$[2],":D701"
350 FOR I=1 TO 16 @ L(I)=0 @ NEXT I @ T$[960]=" "
355 CREATE Q2$,5,256 @ ASSIGN# 1 TO Q2$ @ N=0
```

```
360 !
365 ! Make room for test in alphabetical index.
370 !
375 FOR P=1 TO 841 STEP 60 @ IF C$[1,50]<T$[P,P+4 OR T$[P,P+3]="    " THEN 385
380 NEXT P
385 FOR J=841 TO P STEP -60 @ I=INT(J/60)+1 @ L(I+1)=L(I)
390 T$[J+60,J+119]=T$[J] @ NEXT J
395 !
400 ! Create a file for the test data.
405 !
410 N=N+1 @ L(I)=N @ CREATE "TEST-"&VAL$(N)&Q1$,65,256
415 !
420 ! Update TOC and test file.
425 !
430 CRT OFF @ T$[P,P+59]=C$ @ ASSIGN# 1 TO Q2$ @ PRINT# 1 ; N,L(),T$
435 ASSIGN# 1 TO "TEST-"&VAL$(L(I))&Q1$
440 PRINT# 1 ; A(),R(,),D(,),C(,),B1(),B2(),DO$
445 FOR I=1 TO 6 @ Q$=GET$(TO$(I)) @ PRINT# 1 ; Q$ @ NEXT I
450 ASSIGN# 1 TO * @ CLEAR @ CRT ON
455 !
460 SUBEND
```

VAR	OCCURS IN LINE	
C $	100 ,125 ,125 ,150 150 ,150 ,200 ,375 430	test info from TOC (see main program xref)
A ( )	100 ,440	test information (see main program xref)
R (,)	100 ,440	range parameters (see main program xref)
D (,)	100 ,440	test meter data. (see main program xref)
C (,)	100 ,440	check meter data (see main program xref)
B1( )	100 ,440	no. of readings at each point of test meter
B2( )	100 ,440	no. of readings at each point of check meter
D0$	100 ,125 ,150 ,440	date of test
T0$	100 ,125 ,445	test and check meter info (see main program)
L ()	120 ,180 ,250 ,350 385 ,385 ,410 ,430 435	array of file name numbers. subscript corresponds to the alphabetical element no.
T $	120 ,180 ,200 ,250 260 ,260 ,260 ,260 350 ,375 ,375 ,390 390 ,430 ,430	table of contents (TOC) file. contains an array of elements in format of C$
Q1$	125 ,125 ,345 ,410 435	contains ".CALDAT" and is used to save memory
Q2$	125 ,180 ,355 ,355 430	contains "CONTENTS.CALDAT" and is used to save memory
R	160 ,160 ,210 ,210 235 ,235 ,270 ,275 325 ,325 ,335 ,335	information about user's reply
N	180 ,250 ,295 ,355 410 ,410 ,410 ,410 430	no. of tests in the TOC
P	200 ,200 ,200 ,255 260 ,260 ,260 ,260 260 ,260 ,260 ,260 375 ,375 ,375 ,375 375 ,380 ,385 ,430 430	position of test in TOC T$
I	200 ,250 ,250 ,255 260 ,350 ,350 ,350 385 ,385 ,385 ,410 435 ,445 ,445 ,445	index no. of test
J	385 ,385 ,390 ,390 390 ,390	loop control
Q $	445 ,445	intermediate string for copying T0$() to disk

```
100 SUB "TALK" (A,D$,Q)
105 !
110 ! This program is the software interface between the HP and
115 ! the standard.  JUL 87
120 !
125 ! INPUT: A=bus address, D$=key sequence, Q=no. of queries;
130 ! OUTPUT: D$=last ENTERed info, Q=-1 if successful.
135 !
140 ! ON INTR tells HP where to go when standard has data to send
145 ! and program isn't in the process of ENTERing it.
150 !
155 ON INTR 7 GOTO 280 @ DIM I$[20]
160 !
165 ! Have HP SUBEXIT if 5 seconds elapse before the standard
170 ! completes a handshake (i.e. acknowledges data it said it
175 ! could acknowledge).
180 !
185 SET TIMEOUT 7;5000 @ ON TIMEOUT 7 GOTO 335 @ I$="ERROR"
190 !
195 ! Send request. WAIT 1500 is needed because interrupt must
200 ! be requested before it's enabled. (HP quirk?)
205 !
210 OUTPUT A USING "K" ; D$ @ RESET 7 @ WAIT 1500
215 !
220 ! Head of loop that shows all queried info.
225 !
230 Q=Q-1 @ IF Q=-1 THEN ON ERROR GOTO 335 @ D$=I$ @ GOTO 335
235 !
240 ! Wait for standard to interrupt.  If a minute passes without
245 ! interrupt then abort wait and warn user.
250 !
255 ON TIMER# 1,60000 GOTO 310 @ ENABLE INTR 7;8
260 GOTO 260
265 !
270 ! Get data if no problems.
275 !
280 OFF TIMER# 1 @ IF SPOLL(A)=117 THEN ABORTIO 7 @ RESET 7 @ GOTO 280
285 IF SPOLL(A)>90 THEN DISP "Bus Error. ";@ GOTO 320
290 ENTER A USING "#,K" ; I$@ DISP I$ @ GOTO 230
295 !
300 ! Warn user about DC offset or lengthy auto-zero.
305 !
310 OFF TIMER# 1 @ DISP @ DISP "Phase standard malfunction." @ DISP
315 BEEP 70,100 @ BEEP 100,150 @ BEEP 70,150
320 DISP "Press <CONT> when ready." @ PAUSE
325 CLEAR 7 @ RESET 7
330 !
335 OFF ERROR @ ABORTIO 7 @ SUBEXIT
```

```
VAR     OCCURS IN LINE
A       100 ,210 ,280 ,285      address of phase standard
        290
D $     100 ,210 ,230           instruction string for standard
Q       100 ,230 ,230 ,230      no. of queries to ENTER
I $     155 ,185 ,230 ,290      string ENTERed from standard
        290
```

```
100 SUB "YESNO" (R)
105 !
110 ! This program has the user select 'yes' or 'no' by acting
115 ! on keys Y and N.  JUL 87
120 !
125 OPTION BASE 1@ OFF CURSOR @ ON KYBD K,"YyNn"&CHR$(128) GOTO 135
130 GOTO 130
135 OFF KYBD
140 K=POS("YN"&CHR$(128)&"yn",CHR$(K)) @ IF R>3 THEN R=R-3
145 ON R GOTO 150,155,165
150 DISP "Yes." @ GOTO 160
155 DISP "No."
160 OFF CURSOR @ WAIT 1500
165 ON CURSOR
170 SUBEND
```

VAR	OCCURS IN LINE	
R	100 ,140 ,140 ,140 140 ,145	user's reply. 1=yes; 2=no; 3=abort and go to the main menu
K	125 ,140	programmed key that the user enters

```
100 SUB "ZERO" (Z$,I1,J1,A(,))
105 !
110 ! This program zeros A(1 to I1, 1 to J1). JUL 87
115 !
120 OPTION BASE 1@ DISP " zeroing ";Z$
125 FOR I=1 TO I1 @ IF NOT (I MOD 10) THEN BEEP 20,2
130 FOR J=1 TO J1-3 STEP 4 @ A(I,J),A(I,J+1),A(I,J+2),A(I,J+3)=0 @ NEXT J
135 NEXT I @ SUBEND
```

VAR	OCCURS IN LINE	
Z $	100 ,120	text name of array being zeroed
I1	100 ,125	size of 1st dimension of array A(,)
J1	100 ,130	size of 2nd dimension of array A(,)
A (,)	100 ,130 ,130 ,130 130	array to clear to zeros
I	125 ,125 ,130 ,130 130 ,130 ,135	1st dimension loop control
J	130 ,130 ,130 ,130 130 ,130	2nd dimension loop control

NBS-114A (REV. 2-8C)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO. NBS/SP-250/26	2. Performing Organ. Report No.	3. Publication Date May 1988

4. TITLE AND SUBTITLE

NBS MEASUREMENT SERVICES:
NBS Phase Angle Calibration Services

5. AUTHOR(S)

R. S. Turgel, J. M. Mulrow and D. F. Vecchia

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

NATIONAL BUREAU OF STANDARDS
U.S. DEPARTMENT OF COMMERCE
GAITHERSBURG, MD 20899

7. Contract/Grant No.

8. Type of Report & Period Covered

Final

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)

Same as item 6.

10. SUPPLEMENTARY NOTES

Library of Congress Catalog Card Number 88-600501

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

The National Bureau of Standards (NBS) offers a calibration service for audio-frequency phase meters. The calibrations are based on a phase angle standard developed at NBS that generates two sinusoidal signals, over a frequency range of 2 hertz to 50 kilohertz, displaced relative to one another by a precisely known phase angle. The signal amplitudes are independently adjustable on each channel from 0.5 volts to 100 volts. The angular resolution is better than 0.002° at the low end of the frequency range and decreases to 0.005° at the high end. The uncertainty of the phase angle between the two signals generated by the standard varies from 0.005° to 0.04° depending on frequency and amplitude.

Using the phase angle standard, phase meter readings are obtained at selected test points. From the calibration data, the phase meter response characteristic is determined and is compared to that of an ideal meter having a linear characteristic. If the phase meter response conforms to the linear model, a straight-line calibration curve is derived from the data and serves to calculate corrected readings. From the statistical parameters associated with the calibration curve, it is possible to estimate the limits of offset between the calibrated meter and the calibration standard. By extension, the uncertainty of readings of the phase meter in the user's laboratory can be estimated.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

calibration; calibration curve; linear model; phase meter; phase standard; uncertainty

13. AVAILABILITY

☒ Unlimited

☐ For Official Distribution. Do Not Release to NTIS

☒ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

☐ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

114

15. Price

USCOMM-DC 6043-P80

THE SP 250 SERIES ON NBS MEASUREMENT SERVICES*

SP 250–1 Spectral Radiance Calibrations
SN003–003–02792–8 $3.50

SP 250–2 Far Ultraviolet Detector Standards
SN003–003–02810–0 $4.25

SP 250–3 Radiometric Standards in the Vacuum Ultraviolet
SN003–003–02806–1 $6.50

SP 250–4 Fricke Dosimetry in High-Energy Electron Beams
SN003–003–02816–9 $2.75

SP 250–5 Alpha-Particle Calibrations
SN003-003-02823-1 $2.00

SP 250–6 Regular Spectral Transmittance
SN003–003–02805–3 $3.25

SP 250–7 Radiance Temperature Calibrations
SN003–003–02827–4 $2.25

SP 250–8 Spectral Reflectance
SN003–003–02812–6 $7.00

SP 250–9 Calibration of Beta-Particle-Emitting Ophthalmic Applicators
SN003–003–02817–7 $2.00

SP 250–10 Radioactivity Calibrations with the "4π" Gamma Ionization Chamber, and Other Radioactivity Calibration Capabilities
SN003–003–02824–0 $2.25

SP 250–11 Dosimetry for High-Dose Applications

SP 250–12 Neutron Personnel Dosimetry
SN003–003–02811–8 $2.50

SP 250–13 Activation Foil Irradiation with Californium Fission Sources

SP 250–14 Activation Foil Irradiation by Reactor Cavity Fission Sources

SP 250–15 Photometric Calibrations
SN003-003-02835-5 $4.25

SP 250–16 Calibration of X-Ray and Gamma-Ray Measuring Instruments

SP 250–17 The NBS Photodetector Spectral Response Calibration Transfer Program

SP 250–18 Neutron Source Strength Calibrations

SP 250–19 Calibration of Gamma-Ray-Emitting Brachytherapy Sources

SP 250–20 Spectral Irradiance Calibrations
SN003–003–02829–1 $5.50

SP 250–21 Calibration of Beta-Particle Radiation Instrumentation

SP 250–22 Platinum Resistance Thermometer Calibrations
SN003–003–02831–2 $17.00

SP 250–23 Liquid-in-Glass Thermometer Calibration Service

SP 250–24 Standard Cell Calibrations
SN003–003–02825–8 $2.75

SP 250–25 Calibration Service for Inductive Voltage Dividers

SP 250–26 Phase Angle Calibrations

SP 250–27 AC–DC Difference Calibrations

SP 250–28 Solid-State DC Voltage Standard Calibrations
SN003-003-02842-8 $2.00

SP 250–29 Traceable Frequency Calibrations
SN003-003-02844-4 $2.25

SP 250–30 GOES Satellite Time Code Dissemination: Description and Operation
SN003-003-02845-2 $2.75

SP 250–31 Mass Calibrations at the National Bureau of Standards

SP 250–32 A Calibration Service for 30 MHz Attenuation and Phase Shift

SP 250–33 A Calibration Service for Voltage Transformers and High-Voltage Capacitors

* Those entries containing a stock number (003–003–––) and price can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. GPO will accept checks, money orders, VISA, and Mastercharge. For more information, or to place an order, call (202) 783–3238. Be sure to use the stock number in all orders. Titles without stock numbers are in preparation.

U.S. Department of Commerce
National Bureau of Standards
Gaithersburg, MD 20899

Official Business
Penalty for Private Use $300